ECONOMICAL EVALUATION OF FLOOD RISK THROUGH URBAN LAND-USE MODEL

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Abstract: This study aims to assess the amount of damage of flood disaster including both direct and indirect damages by analyzing land price and land-use via a Hedonic land-use model. A logit type random bid rent model is estimated for the Yamatogawa River Basin in Nara Prefecture, Japan, based on land-use data as well as observed land price, which is considered to be maximum bid-rent value. The estimated parameters revealed that flood risk makes less evaluation of land in all land-use types. We could also estimate the total suppressed property value by the flood risk as 1.7 billion yen in the analyzed area.

Keywords: flood risk, hedonic, land-use model, land price, bid rent

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1. THE METHODOLOGY OF FLOOD DAMAGE EVALUATION

Japan is in the environment easy to receive natural disasters, such as flood, earthquake, landslide, tsunami, high tide, volcanic eruption and so on. Therefore, the disaster prevention investment has been considered important. For the natural disaster occurred in such a small probability as once per one hundred years, however, it is hard for citizens to understand the effect of the disaster prevention investment. Furthermore, in large scale disaster does not only invite direct damage of human life and properties, but also indirect damage resulted from the stop/decrease of social and economic activities due to the disaster. It is very difficult to assess the precise amount of the indirect damage.

This study aims to assess the amount of damage of flood disaster including both direct and indirect damages by analyzing land price and land-use via a Hedonic land-use model. A logit type random bid rent model is estimated based on land-use data as well as observed land price, which is considered to be maximum bid-rent value. This model integrates random bid rent theory with actual land price data in order to appropriately capture the evaluation of land users, with considering the possibility of flood damage. The model was applied to the Yamatogawa River basin in Nara Prefecture. The estimated parameters revealed that flood risk makes less evaluation of land in all land-use types. We could also estimate the total suppressed property value by the flood risk as 1.7 billion yen in the analyzed area, including both direct and indirect damages.

The remainder of this paper is composed of four sections. Section2 discusses the methodology of flood damage evaluation and the applicability of hedonic approach. Section 3 explains the land-use model and parameter estimation procedure, followed by the section 4, showing the result of the application in the Yamatogawa River basin. At last, section 5 summarizes the findings of the study and remaining issues for the future studies.

2. THE METHODOLOGY OF FLOOD DAMAGE EVALUATION

2. 1 Conventional way of flood damage evaluation

As reviewed by Oliveri and Santoro (2000), estimation of flood damages represents a fundamental step for the economic analysis of a flood control project. In particular, frequency-damage functions, are one of the fundamental pieces of information upon which expenditure decisions should be based. In order to get those functions, hydrological and hydraulic data are combined with physical and socio-economic information. Due to the relatively frequent floods, flood damage evaluation first developed for the floodplain in large primarily used as agricultural land, where spatially coarse hydraulic model were applied to large catchments.

A significant portion of damage, however, arises by flooding the urban properties located on small drainage areas, frequency-damage relationship, in detailed local areas should be obtained. A frequency-damage relationship is usually established by the combination of the three steps; first the return periods of heavy rainfalls are estimated based on local meteorological history, second, the flooding phenomena for those rainfalls are prospected through hydraulic models and find the estimated water depths in the flooding area. At last, multiply the empirically estimated depth-damage relationship, as shown by Appelbaum, 1985), Mc Bean et al. (1988), with the amount of the assets and properties in the area, investigated.

Flood damage is actually affected not only by water depth, but also by many different factors such as the duration of flooding, the velocity of flood waters, their sediment load, the availability of a warning system and the local increase of costs due to the occurrence of the flood event. Such factors can not be easily estimated even by the state-of-art hydraulic technique, then, those parameters have been not taken into account in the present analysis.

Besides the physical issue of floods, economic evaluation simply calculate the expected average damage has been criticized, by Graham(1989) , Morisugi et al (1995) and evaluation methods considering option value were proposed.

However, above approaches based on the prospected phenomena of flooding events, the result strongly depends on the scenario of damages, and it is very difficult for ordinal citizen to understand the contents of those scenarios with very low frequencies such as once per 100 years, especially scenarios about the indirect damages.

2. 2 The approach of this research

Alternately, we pay attention rather on the ordinal days, than disaster time. The economic activity having enormous indirect damage is assumed should not decide to locate at the place subjected with high possibility of flooding. Consequently, land price at such spots with higher risk of flood damage would be lowered than the value expectable if no flood risk were there.. Hedonic land price model containing natural disaster risk as one explanatory factor is, then, considered as an alternative way of economic evaluation of natural disaster risk.

Miyata and Adachi (1994) estimated a land price model considering the effect of flood control works in Chitose River Basin. Hedonic modelling is based on the methodology that the observed land price is regressed to the environment factors of conveniences, accessibilities, amenities, as well as natural disaster safeties in the area. Therefore, if the correlation between the disaster risk and the other environment factor is high, the influence of the disaster risk can not be separated, due to multi-correlation, Furthermore, it is not easy to gather enough land price data information for both places of high risk and low risk.

In order to consider the flood control effect on land-use change, Takagi et al (1993) proposed a simple logistic growth curve model to explain the development speed affected by the flood risk. They first consider the change of built area by the trend curve, then hedonic land price model was applied. Bollens et al (1989) distributed questionnaire to 106 developers and builders in ten US cities having flood plain policies. They reported that floodplain policy has negligible effect on whether development does or does not occur in a floodplain, however, significant effects on which structures are built. Permitting similar situations in Japanese cities, the present approach independently considering land-use and land price seem not much effective.

This study uses the logit type land-use model integrating random bid rent theory with actual land price data, developed by Haque and Okumura (2003). In this model , land value function is estimated based on the observed land price and land-use data, which is available at lager number of spots than land price. The model unifying land-use and land price enable us to capture the effect of additional construction cost for flood proof buildings, implied by Bollens et al (1989) .

3. THE LAND-USE MODEL CONSIDERING FLOOD RISK

3.1 Random bid-price model formulation

Considering each individual land lot's characteristics in terms of planning restrictions, accessibility, neighbourhood's land-use, as well as risk of flood, potential land users make expectation of future profit or advantage for the desired usage, if he/she can buy the lot. They express their own evaluation in term of the present value of the expected future monetary flows, in front of the present landlord in each land market; that is called as a bid price. Because their expectation also depends on uncertain factors such as future financial and economic trends, bid price by land-user j for lot n; (U_{in}) is captured as the average value; V_{in}, a function of land lot's characteristics, and statistically distributing error term; ε_{in} .

$$U_{in} = V_{in} + \varepsilon_{in} \tag{1}$$

Then, P_{in}; the probability of that this land lot n is sold to the j *th* user and such land-use type j is realized can be written as,

$$P_{in} = \Pr ob(U_i \geq U_j, \forall j \neq i) \tag{2}$$

When we assume that the error part ε_{in} obeys to mutually independent identical Gumbel distribution, the following logit model can be derived.

$$P_{in} = \exp(V_{in}) / \sum_j \exp(V_{jn}) \tag{3}$$

If we could observe the trade price of each land lot, it might be very close to the maximum bid price; $\max_j U_{jn}$, and then its systematic substitute; $\max_j V_{jn}$. As a proxy land price of the actual value in transactions, we use the '**published price**' which is announced each year by the MLIT and local government of Prefectures. That published price; OP_n , being an average estimated price of several qualified real estate appraisal professionals, usually reflects reputation and expectation of the region, besides the actual trade price. Then we consider unexplained regional effect parameter; θ^a, as well as a zero-mean normal distributing error term; ϕ_n.

$$OP_n = \max_j V_{jn} + \sum_a \theta^a \varphi_n^a + \phi_n \tag{4}$$

where, φ_n^a is a dummy variable taking one, if land-lot n is included in region a.

3.2 Parameter estimation using both land-use and land price

When we get the observed land-use type through dummy variable δ_{in} for land-use type i at land lot n, we can derive the logarithm of the joint probability for the observed land-use as follows,

$$L^{use} = \prod_n \prod_i \delta_{in} \log P_{in} \tag{5}$$

Till the date, conventional logit models have been estimated based solely on the observed land-use pattern; δ_{in} through this log-likelihood function, independent from the land price information; OP_n, which has been energetically used to build up land price functions in Hedonic approach literatures.

By adding the logarithm of probability concerning the normal distributed error ϕ_n to equation 5, we can get a composite log-likelihood function, which should be maximized when we estimate unknown parameters in bid rent functions as well as regional dummy parameters; θ^a.

$$L = \prod_n \prod_i \delta_{in} \log P_{in} + k \cdot d_n \cdot \log \Phi[OP_n - (\max_j V_{jn} + \sum_a \theta^a \varphi_n^a)] \tag{6}$$

where, $\Phi[\bullet]$ is a normal distribution probability function with zero mean and variance of σ^2, d_n is a dummy variable for land price observation in each land lot n. k is a weight determining the relative importance of the first and the second terms in the likelihood function, set as total sample number / number of price observations.

Through maximization of equation 6, we can get the bid price function for each type of land-use, which causes high probability of the observed land-use as well as the observed land price.

4. ANALYSIS IN THE YAMATOGAWA BASIN

4.1 The study area

Yamatogawa basin of 1,070km^2 is locating Osaka and Nara Prefecture, parted by the bottle neck of Kamenose land slide area, often receive inundations inside a levee in Nara area, by intensive rainfalls occurred in 1982, 1995 and 1999. Especially in 1982, the basin suffered inundations of 3,127.8 ha area with 21,696 damaged buildings in total. Especially near Oji JR Station, which is an area with the lowest altitude on the Nara basin, the flooded water depth became more than 1 m.

In this research, frequent inundated areas between Yamato-Kouriyama City and Oji Town along the major branch, Sahogawa-River and the main Yamatogawa River, are selected as the study area. We take the locations whose altitudes are between 30m and 60m into account. We prepare land-use data of 10m meshes, but operational reason, we use 16,386 meshes out of 459,041.

4.2 Discussion on the estimated model parameters

The estimated parameter values of the land-use model is shown in table 1, the numbers of meshes classified by the observed and the reproduced land-uses are shown in table 2. Observed and reproduced land-uses are shown in

Table 1: The estimated parameters of the land-use model

variable	Industrial use building	Commercial use building	Residential use building	Forest and agricultural land	Bareland, lots under construction
No of inundation experiences	-0.780	-0.858	-0.459	-0.556	-0.710
	(-6.84)**	(-7.90)**	(-13.3)**	(-13.51)**	(-9.15)**
Distance to road, 15m or wider	-0.001	-0.003	-0.002	-0.001	-0.002
	(-4.26)**	(-10.21)**	(-10.67)**	(-4.86)**	(-6.56)**
No. of industrial meshes within 100m	0.012	-0.011	-0.016	-0.018	-0.011
	(21.88)**	(-8.08)**	(-13.05)**	(-26.35)**	(-11.55)**
No. of commercial meshes within 100m	0.012	0.042	0.003	0.0004	0.009
	(5.28)**	(26.39)**	(1.97)*	(0.465)	(5.17)**
No. of residential meshes within 100m	-0.001	0.001	0.013	-0.008	-0.004
	(-0.51)	(1.13)	(29.49)**	(-20.31)**	(-5.77)**
Urbanization promoting area	0.731	-0.081	0.044	-0.108	1.243
	(6.87)**	(-0.82)	(0.865)	(-2.69)	(17.28)**
constant	8.843	9.571	10.567	12.628	10.176
	(82.10)**	(117.7)**	(22.62)**	(305.5)**	(136.7)**
Variance of error in land price	0.898	Dummy in North Side	0.314	Dummy in South Side	-0.443
	(85.17)**		(4.74)**		(-12.75)**
Initial log likelihood	-135604		likelihood ratio		0.76
Final log likelihood	-31889		number of samples		16386
		(t-statistics), **:significant in 1%, *:significant in 5%			

Table 2: Number of meshes classified by the observed and reproduced land-use

observed use / reproduced use	Industrial use building	Commer-cial use building	Residen-tial use building	Forest, agricul-tural land	Barelnd, under constr.	total no.	fit ratio (%)
Industrial bldg.	296	65	126	336	100	296	32.1
Commertial bldg.	74	63	132	219	47	535	11.8
Residential bldg.	225	215	899	1775	278	3392	26.5
Forest, Agric.lnd.	591	453	2235	7465	812	11556	64.6
Bare, construct.	0	0	0	0	0	0	0.0
total number	1186	796	3392	9795	1237	16406	
fit ratio(%)	25	27	26.5	76.2	0		53.2

figure 1 and figure 2, respectively. Figure 3 shows the correlation between the predicted maximum bid price and the observed price in 1999 for 47 spots with observations; over estimation of the land price in most spots are detected.

The likelihood ratio concerning to the fit of land-use is 0.76 and the explanation power for land-use is good, but the matching percentage isn't too high with 53.2%. As for the matching percentage for each use, forest and agricultural land are the highest. Most parameters are statistically significant, and they have the proper signs as shown in table 1.

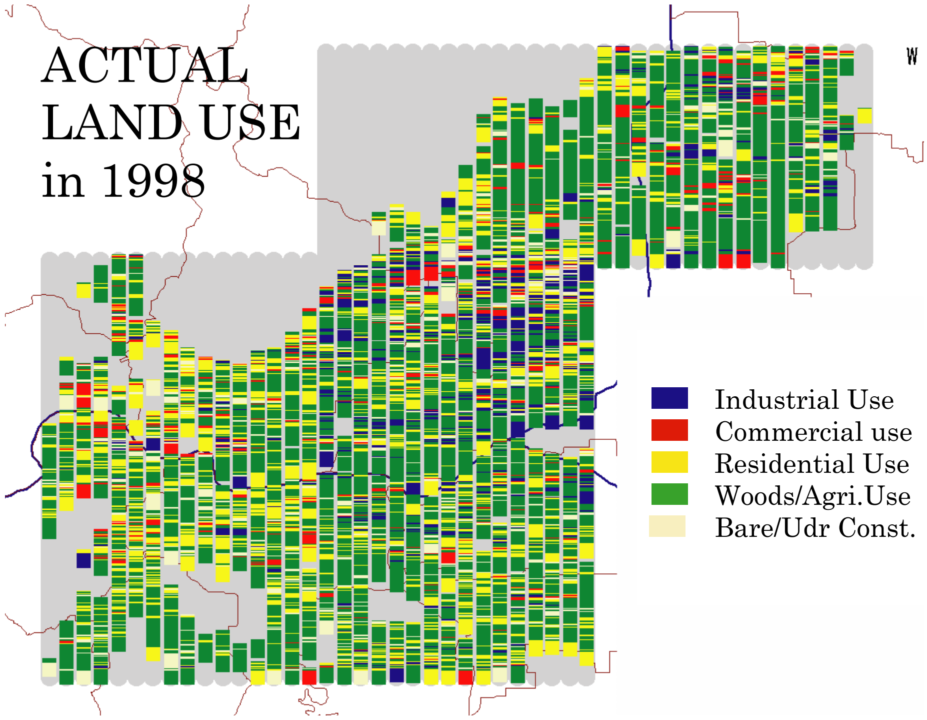

Figure 1: Observed land-use in 1998

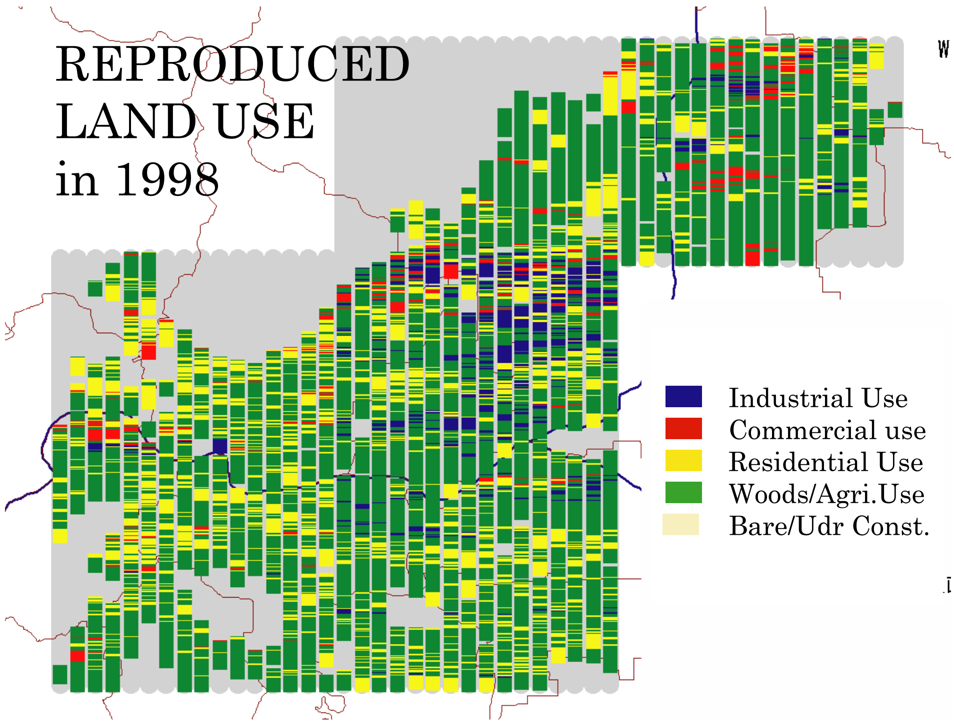

Figure 2: Reproduce land-use by the model

The parameters for "the experienced number of inundations" are a significantly negative to all uses; it shows that the land value is discounted with certain percentages by the experience of the inundation damages, taking into account that the bid price functions are formulated in log-linear form. For commercial and industrial uses, the discounting effects are $0.42 = \exp(-0.858)$ and $0.46 = \exp(-0.780)$, respectively, due to the significant direct/indirect damage

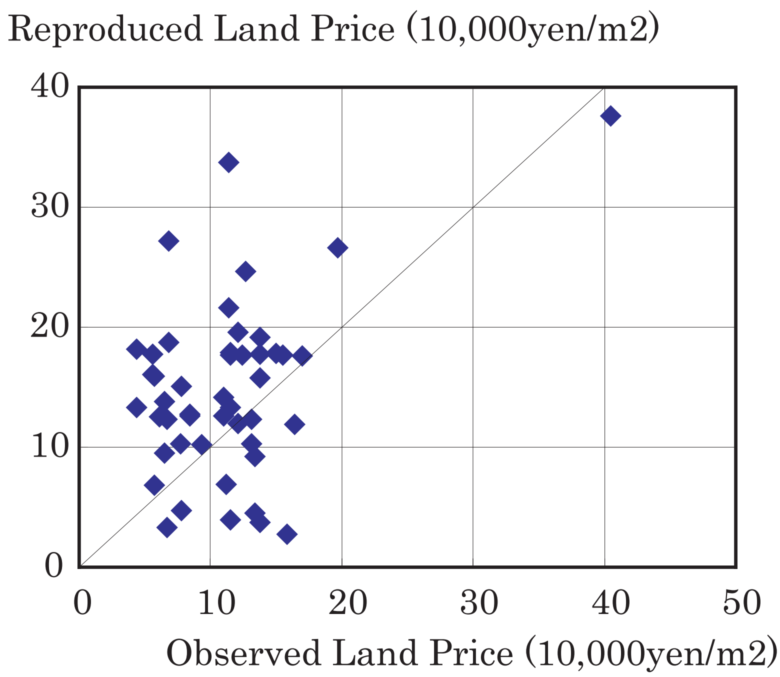

Figure 3: Observed and reproduced land price

to business activities by the flood water.

It seems unrealistic that the estimated effect on the residential use; $0.63 = \exp(-0.459)$ is smaller than that for bare land and lot under construction; $0.49 = \exp(-0.710)$, and that for forest and agricultural land; $0.57 = \exp(-0.556)$. It is caused by that not a few number of houses including the historical farmhouses existed in the area where there were inundation damage. If we picked up the houses constructed recent decades, the result may possibly be different. We should also sub-classify the forest and agricultural land, because the influence of flood may be very different for the forest and agricultural land.

In order to include the flood risk, we also tried to use the expected depths of flood water, published in Web site of the Yamatogawa River Work Office, but any significant result wasn't obtained in the estimation. It implies that the land market reflects not the situation in future, but the really experienced situation.

4.3 Calculation of the amount of the flood damage

If the flood risk would disappear, the price of land rises. Considering that each mesh represents the surrounding area of $10m \times 250m = 2{,}500m^2$ due to the sampling in the analysis, we sum up the effects of flood experience for the meshes with inundation history, in order to estimate the loss of the total land value due to the flood risk. The result is 1.7 billion yen as shown in table 3, including the largest part of 980 thousand million yen come from the forest and agricultural land, followed by damage in residential built area, and commercial use.

Table 3: The loss of the total land value caused by the flood risk

(unit: thousand million yen)

Land-use	Industrial use bldg.	Commercial use bldg.	Residential use bldg.	Forests, agricult.	Bareland, Construct	Total
Loss	72	243	360	986	28	1,689

Table 4: The prospected number of land-uses with and without flood risk

Land-use	Industrial use bldg.	Commercial use bldg.	Residential use bldg.	Forests, agricult.	Bareland, Construct	Total
with risk	0	0	33	8	0	41
without risk	4	5	0	30	0	41

Table 5: The estimated amount of total land value with and without flood risk

(unit: thousand million yen)

Total land value with flood risk	Total land value without risk	difference
35,144	36,932	1,788

4.4 Simulation of land-use change after an ideal flood control

Further, we can simulate the situation that flood risk is totally removed by an ideal flood control measures, permitting any changes of land-use. Input values of "the experienced number of inundations" for all meshes are hypothetically set as zero, and the land-use and land price are calculated by the model.

First, the number of the meshes which had the change of land-use is shown in table 4. Not so many meshes have the change of use, mainly Industrial, commercial and agricultural uses instead of residential buildings. Total value of land are estimated as table 5, which shows the increase of 1.8 billion yen, owing to the diminished flood risk. This value is 5.8% larger than the value in Table 3, including the effect of that valuable land-use become possible at 0.3 % of the meshes in the area. It shows the influence is relatively large for these meshes.

5. CONCLUDING REMARKS

This research proposed a technique to capture the economical effect of floods including direct and indirect effects, by focusing on the difference of land-use as well as land price of the spots with and without the flood risk. This method goes around the difficulties in setting plausible scenarios of flooding phenomena and subsequent damages in social and economic activities. The land-use model based on random bid price theory successfully provided the unified framework to deal land price and land-use data, at once, and avoid the problem of data shortage of land price observations.

Application to the Yamatogawa River basin in Nara Prefecture, Japan showed the statistically significant effects of flood risk onto the reduction of land values due to the risk, although over estimation is detected for land price. The estimated parameter values gave the estimation of the total economic effect of flood risk, including indirect damage as 1.7 billion yen. Land-use simulation also provided the estimation of the increased value of land owing to the flexible land-use free from the flood risk. Although these estimation may be excessive due to the over estimation of the price, this study has proved the applicability of the proposed methodology.

There are several issue for the future studies. At first, we should improve the explanatory power of the model and avoid the over estimation of land price. One possible way is to increase the weight parameter in equation 7 and give heavier weight on the observed price. Second, classification of land-use must be reconsidered; forest and agricultural land should be divided for example. More precise altitude data by laser scanner on an airplane may help improving this analysis; it may enable the estimation of water depths in the previous floods, usable in the model instead of the times of inundations.

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