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Spatial Analysis to Identify Factors Affecting Residential Land Prices in Disaster Areas

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Abstract: On March 11, 2011, a catastrophic earthquake struck Japan's Tohoku area, which faces the Pacific Ocean. In this study, a multivariate spatial analysis was conducted to analyse the factors affecting residential land prices in the disaster-stricken area using the Hedonic Price Method. For the analysis, we first, collected spatial data, including land price maps, tsunami damage area map, flood hazard map, landslide hazard map, railway map, zoning map, and public building map of Miyagi prefecture. Second, we examined the extent to which the damage caused by the tsunami inundation can influence land prices, in order to clarify the relationship between natural disasters and land price fluctuations. The results of the multivariate analysis concluded that the tsunami inundation affected the price of land, particularly after the Great East Japan Earthquake (2011) in Miyagi prefecture. Furthermore, the degree of the tsunami inundation and the distance from public housing constructed after the disaster influenced land price fluctuations after the earthquake. In other words, the human settlements have been affected by disaster damage and reconstruction plan. Present studies have demonstrated the residents' attitudes towards housing location choices before and after the earthquake disaster. By improving the precision of the multiple regression analysis in the future, we will be able to utilize the experiences of previous disasters as lessons learnt for safety and sustainability, particularly Sustainable Development Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable.

Keywords: multivariate spatial analysis, land price, residential location choice, Great East Japan Earthquake, tsunami

1. Introduction

On March 11, 2011, the catastrophic Great East Japan Earthquake struck Japan's Tohoku area, which faces the Pacific Ocean. Then, municipal governments pinpointed the disaster risk areas and the residents moved from those areas to inland safety areas after the earthquake. In other words, the residential areas were relocated after the 2011 earthquake.

In this study, we have discussed the conditions of the disaster-stricken residential area before and after the disaster, using land prices as objective indicators. We have used the useful public geospatial information data related to real estate, natural disasters, and public facilities to develop a general method which can be used anywhere.

2. Study Method

The target area of this study is Miyagi prefecture situated in Tohoku area. The coastal areas were damaged by the ensuing tsunami and some inland areas were damaged as well after the Great East Japan Earthquake. Moreover, riverside areas are known to be flood risk and hilly areas, a landslide disaster risk.

In this study, a multivariate spatial analysis was conducted to analyse the factors affecting residential land prices in the disaster-stricken area using the Hedonic Price Method.

For the analysis, we first, collected spatial data, including land price maps, tsunami damage area map, flood hazard map, landslide hazard map, railway map, zoning map, and public building map of Miyagi prefecture. Figure 1 shows the areas damaged by the tsunami in 2011, hazardous locations and land price research sites in Miyagi prefecture.

Second, we examined the extent to which the damage caused by the tsunami can influence land prices in order to clarify the relationship between natural disasters and land price fluctuations. Table 1 shows the candidate variables for multiple regression analysis.

The land price analysis samples included 200 investigation sites where prefectural land price research has been conducted for at least 13 years (2005-2017)[1)]. The samples of the land price variation ratio analysis comprise 315 investigation sites where prefectural land price research has been conducted for at least 8 years (2010–2017)[1)].

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Table 1. Candidate variables for multiple regression analysis

VARIABLES		SUMMARY
Objective Variable	Land price of Residential Area	・Land price[1)] [yen/m²] ・Land price variation ratio[1)] [%]
Expla-natory Variable	Distance to the nearest station	Distance to the resident's nearest station[1)] [m]
	Times taken to downtown	Time taken to Sendai station from the resident's nearest station [min.]
	Acreage	Area of Land[1)] [m²]
	Building coverage ratio	Ratio of the building's area to the lot area[1)] [%]
	Floor area ratio	Ratio of a building total floor area to the lot area[1)] [%]
	Road with	With of a frontal road[1)] [m]
	Urbanization promotion area	Urbanization promotion area[1)] (dummy variable)
	Urbanization control area	Urbanization control area[1)] (dummy variable)
	Outside of city planning area	Outside of city planning area[1)] (dummy variable)
	City gas	City gas service area[1)] (dummy variable)
	Sewage system	Sewage service area[1)] (dummy variable)
	Coastal area	Coastal area (dummy variable)
	Tsunami inundation depth	Depth by tsunami inundation in 2011[2)] [m]
	River flood depth	Estimated depth of flood from main River[3)] [m]
	Distance to elementary school	Linear distance to the elementary school [4)] [m]
	Distance to junior high school	Linear distance to the junior high school [4)] [m]
	Distance to Hospital	Linear distance to the hospital [5)] [m]
	Distance to post-disaster public housing	Linear distance to the public housing constructed after the earthquake[6)] [m]

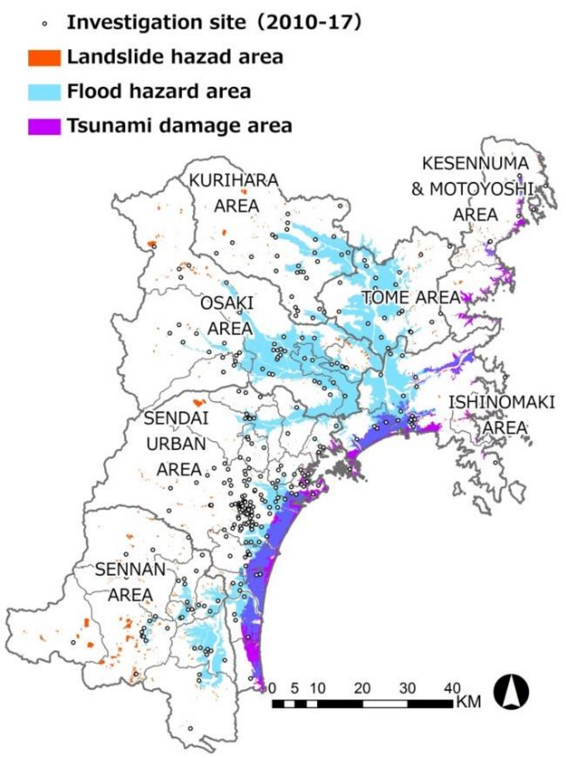

Figure 1. Areas damaged by the tsunami in 2011 and hazardous location in Miyagi prefecture.

3. Results of the analysis

3.1 Analysis of the factors affecting land value

We conducted a multiple regression analysis. The objective variables were land values of each year from 2005 to 2017. Four independent variables were selected as explanatory variables (significance level = 0.05). The disaster level of the 2011 earthquake tsunami and the public transport accessibility are included in the factors affecting land value. The sample size is 200.

Table 2 describes the transition of standard partial regression coefficients as the analysis results. "Distance to the resident's nearest station", "Time taken to Sendai station from the resident's nearest station" and "Tsunami inundation depth" have negative influence on land values. "Urbanization promotion area" and "Floor area ratio" have a positive influence on land values. The influence of "Tsunami inundation depth" on land values was the largest when the earthquake occurred in 2011.

3.2 Analysis of the factors affecting land value variation ratio

Figure 2 describes the transition of land value variation ratio to the same month of the previous year for 11 terms. The land value variation ratio during 2010-2011 showed a larger decline than the other terms.

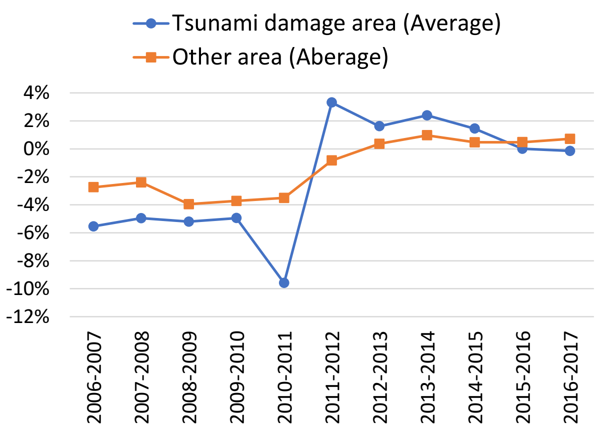

Figure 2. Transition of land value variation ratio.

Next, we conducted other multiple regression analysis. The objective variables were the land value variation ratios compared with 2010. Five independent variables were selected as explanatory variables. The disaster level of the 2011 earthquake tsunami inundation, other natural hazard risks and distance to public facilities are included in the factors affecting land value. The sample size is 315.

Table 3 describes the transition of the standard partial regression coefficients as the analysis results. "Urbanization promotion area" has a positive influence on the land value variation ratios in all terms. "Tsunami inundation depth" has a negative influence on the land value variation ratios in all terms, and it is the largest impact factor in 2011 as compared to 2010. In addition,

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"River flood depth" has a positive influence on the land value variation ratio from 2012. It is believed that the prices of lowland areas near the rivers have risen after the disaster because of relocation to the riverside. Furthermore, "Distance to post-disaster public housing" has a negative influence on the land value variation ratios after 2013 as compared to 2010. It is believed that the land values around the building lots of public housing for earthquake reconstruction have risen after the disaster. On the other hand, "Distance to the hospital" and "Distance to the public school" do not have any influence on the land value variation ratios.

4. Conclusions

Figure 3 describes the spatial distribution of land price variation ratio between 2010 and 2017, based on land assessment and statistical estimation in Miyagi prefecture. Both maps show that land prices tend to increase in the east coastal area around Sendai city or Ishinomaki city. However, the results of the multivariate analysis concluded the tsunami inundation affected the price of land, particularly after the Great East Japan Earthquake (2011) in Miyagi prefecture. Furthermore, the degree of the tsunami inundation and the distance from public housing constructed after the disaster influenced land price fluctuations after the earthquake. In other words, human settlements have been affected by disaster damage and reconstruction plans.

Present studies have demonstrated the residents' attitudes towards housing location choices, before and after the earthquake disaster. By improving the precision of the multiple regression analysis and minimizing the differences between the two maps (Figure 3) in the future, we will be able to utilize the experiences of previous disasters as lessons learnt for safety and sustainability, particularly Sustainable Development Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable.

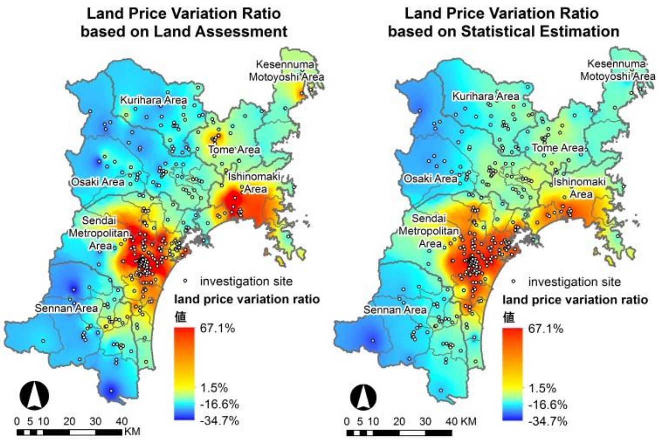

Figure 3. Map of land price variation ratio between 2010 and 2017, based on land assessment (left) and statistical estimation (right).

Table 2. Analysis results of the factors affecting land value (standard partial regression coefficients)

	objective variable (land value)						
explanatory variables	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Distance to the nearest station	-0.274 **	-0.267 **	-0.254 **	-0.242 **	-0.242 **	-0.238 **	-0.235 **
Times taken to downtown	-0.200 **	-0.199 **	-0.197 **	-0.194 **	-0.197 **	-0.198 **	-0.197 **
Urbanization promotion area	0.579 **	0.571 **	0.551 **	0.526 **	0.537 **	0.542 **	0.552 **
Tsunami inundation depth	-0.100 *	-0.103 *	-0.109 *	-0.112 *	-0.116 *	-0.119 *	-0.133 **
adjusted R^2	0.637	0.617	0.574	0.528	0.546	0.550	0.561

	objective variable (land value)					
explanatory variables	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Distance to the nearest station	-0.229 **	-0.224 **	-0.218 **	-0.214 **	-0.210 **	-0.206 **
Times taken to downtown	-0.183 **	-0.174 **	-0.167 **	-0.165 **	-0.167 **	-0.170 **
Urbanization promotion area	0.571 **	0.585 **	0.592 **	0.591 **	0.579 **	0.570 **
Tsunami inundation depth	-0.125 **	-0.125 **	-0.124 **	-0.124 *	-0.126 *	-0.128 *
adjusted R^2	0.571	0.579	0.578	0.571	0.553	0.539

n=200
* significance level 5%
**significance level 1%

Table 3. Analysis results of the factors affecting land value variation ratio (standard partial regression coefficients)

	objective variable (land value variation ratio)						
explanatory variables	**2010-11**	**2010-12**	**2010-13**	**2010-14**	**2010-15**	**2010-16**	**2010-17**
Urbanization promotion area	0.458 **	0.685 **	0.685 **	0.698 **	0.712 **	0.717 **	0.704 **
Floor area ratio	-0.448 **	-0.375 **	-0.275 **	-0.194 **	-0.121 **	-0.018	0.065
Tsunami inundation depth	-0.377 **	-0.107 *	-0.074	-0.076	-0.099 *	-0.129 **	-0.150 **
River flood depth	0.039	0.184 **	0.182 **	0.193 **	0.179 **	0.151 **	0.118 **
Distance to public housing	0.105 *	-0.021	-0.133 **	-0.163 **	-0.177 **	-0.168 **	-0.153 **
adjusted R^2	0.342	0.362	0.428	0.483	0.537	0.587	0.612

n=315 / * significance level 5%, ** significance level 1%

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