An Evaluation of the Living Environment with Flood Disaster Risk in the Lowland of Japanese Depopulation Area

Kojiro WATANABE and Yasunori MUTO

Abstract: In the study, we evaluated the living environment with flood disaster risk to show the future land use policy utilize the green infrastructure (GI). Target area is the Osato district in Tokushima prefecture, Japan. We evaluated the living environment using the proximity of living facilities and the results of flood depth estimation. From the results of the evaluation, at the central area of the town, the living environment was high, but at the same area, there are many vary of the flood depth. In the future, high living environment area with high flood depth needs to be control new development. And farmland near the central area has important role to mitigate flood risk as a GI, so new development in the area needs to be controlled.

Keywords: Flood Risk, Farmland, Green Infrastructure, Living Environment, Land Use

1. Introduction

Recently, Ecosystem-based Disaster Risk Reduction (Eco-DRR) is attracted as a new concept about disaster mitigation. Eco-DRR is a concept to reduce the risk of being exposed to natural hazards by avoiding development of disaster-prone areas as well as by using healthy ecosystems as buffers, to protect people's lives and properties (Ministry of the Environment, 2016). Green Infrastructure (GI) is important factors to realize the concept. But many Japanese land use plan do not have a positive utilization of GI. In the study, we evaluate the living environment with flood disaster risk to show the future land use policy utilize the GI. Target area is the Osato district in Kaiyo town, Tokushima prefecture in Japan.

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2. Osato district

Kaiyo town is depopulated city in the south part of Tokushima prefecture (fig.1). Figure 2 shows the population change in the central area of Kaiyo town. Population over 65 is increasing but other population is decreasing. This pattern is observed in many Japanese provincial cities.

Figure-1 Kaiyo Town

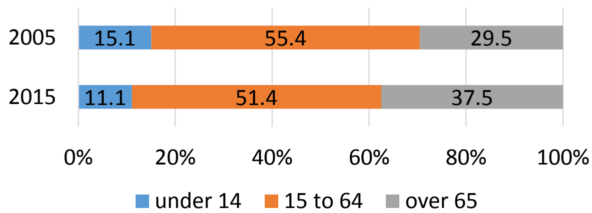

Figure-2 Population change in the central area of Kaiyo town

Kaiyo town has two major city center, Osato and Shishikui district. Osato district (fig. 3) is a central area of Kaiyo town, some living facilities are located in the area. The district is the low-lying area with the mouth of Kaifugawa river. And there are the long pine tree forest facing the beach. The area with west side of Osato district has paddy fields. The coastal forest and paddy field in the district are important GI for disaster mitigation.

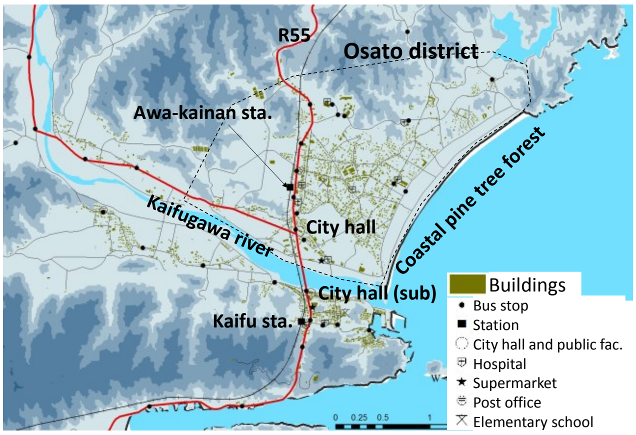

Figure-3 Osato district

3. Living environment evaluation

Evaluation of a living environment and a disaster risk are important factor when we make a land use plan. In the chapter, we evaluates the living environment each mesh.

Ding et al (2009) used the model to estimate satisfaction rate $P(z)$ by each living facilities.

$$P(z) = \exp(-z^2/a) \qquad (1)$$

here, z is the distance from each living facilities. a is parameter.

Evaluation values of living environment in the mesh i $Eval_i$ is calculated by multiplying $P(z)$ for each facilities, using following formula. Spatial unit of $Eval_i$ is the mesh of 250m.

$$Eval_i = \prod P(z) \qquad (2)$$

We used the distance from station, bus stops, super market, elementary school, hospital, post office and city hall to calculate $P(z)$. Parameter a was set so that $P(z)$=0.8 at the area with the distance from bus stop is 300m, the distance from station is 800m and the distance from other facilities are 500m. These distance consider the moving on foot.

From the figure 4, the road side area from Awa-akaishi station to Kaifu station has high values because many living facilities are located in the area. R55 is trunk road in the east side of Tokushima prefecture. So many living facilities are located near the road. In the Osato district, the around of central area ($Eval$=0.01 to 0.1) is low density residential area and farmland mainly.

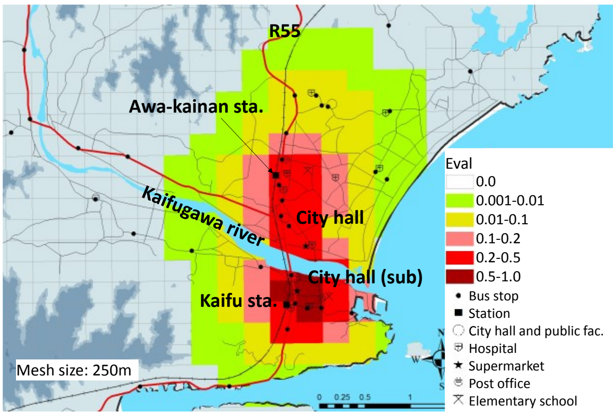

Figure-4 Distribution of *Eval*

4. Disaster risk

In the chapter, we evaluates the disaster risk about flooding. Fluvial flood data of the Kaifugawa river is provided by the National Land Numerical Information download service (open data). 50 years rainfall data is used to make the fluvial flood data. And as an inland flood data, we used the results of flooding simulation by Yokokawa et al. (2019). They used to the typhoon No.12 in 2014 as a rainfall data, and they calculated by the flooding simulation software AFREL-SR (NITA consultants).

Figure 5 shows the distribution of fluvial flood depth. There is no flood risk in the east area of Osato, because elevation of the area is little higher than other area. Road side area of R55 has flood risk. Flood depth over 200cm is estimated near the city hall.

Figure 6 shows the inland flood depth in Zenzougawa basin. Inland flood is estimated at the west side of Awa-kainan station. Land use of the area is paddy fields mainly. So these area is important GI to mitigate flood disaster. Similarly, east side of city hall has many inland flood risk, but the area covered with paddy field also. Land use control is important to mitigate flood disaster in the area.

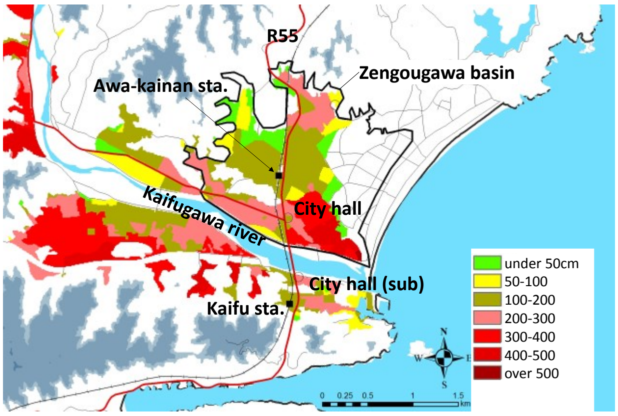

Figure-5 Fluvial flood depth

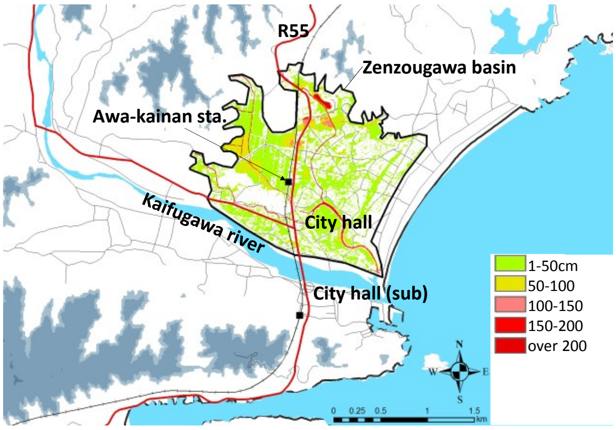

Figure-6 Inland flood depth in Zenzougawa basin

5. Compare with living environment and disaster risk

Table 1 shows the results of cross tabulation with the number of buildings and the flood depth in Zenzougawa basin. In the fluvial flood area, the number of buildings are decreasing in the area with flood depth of 100 to 300cm. But the number of buildings in the area over 300cm and the area under 50cm flooding is increasing. In the case of inland flood area, the number of buildings in the area under 100cm flooding is increasing. Generally, it is thought that inhabitants will select residential area without disaster risk. But in the district, the area with flood risk are selected as new development area.

Table-1 Cross tabulation with the number of buildings and the flood depth in Zenzougawa basin

		Flood depth of fluvial flood[cm]						sum
		1-50	50-100	100-200	200-300	300-400	400-	
Number of buildings	2006	140	297	766	347	33	10	1,593
	2018	147	297	751	341	38	10	1,584
	difference	7	0	-15	-6	5	0	-9
		Flood depth of inland flood[cm]						sum
		1-50	50-100	100-200	200-300	300-400	400-	
Number of buildings	2006	1,194	32	9	18	1	0	1,254
	2018	1,221	33	8	16	1	0	1,279
	difference	27	1	-1	-2	0	0	25

Figure 7 shows the results of cross tabulation with the *Eval* and the flood depth. From the results of the chi-square test, there was no significant differences between the *Eval* and the flood depth.

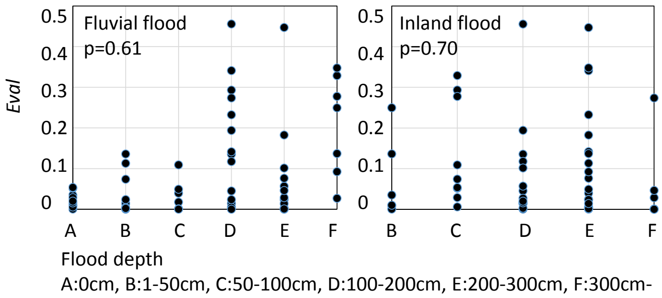

Figure-7 Cross tabulation with the *Eval* and the flood depth

In the area over 100cm fluvial flood, the variation of *Eval* is large. As the reasons, it is thought that the land use near the city hall. The area has high *Eval* because there are many living facilities, but elevation is low and near the Kaifugawa river. According to table 1, the number of buildings in that area is decreasing. But the number of buildings in that area is larger than other area. So, the area needs to develop the flood coping buildings like a high rise buildings and to arrange the evacuation environment, in addition to maintain the river embankment. As the view of the side of land use planning, it will be prohibited the low density development.

In the case of inland flood, because the flooding is estimated for wide area, there are many variation of *Eval*. The area with the high *Eval* and low flood depth is suitable to live for many inhabitants. But some inhabitants will select development area without relation to flood disaster. The risk of inland flood is difficulty to see, so we need to protect new development in the cluster area with high disaster risk of inland flood, like a west side of Awa-kainan station and an east side of city hall.

6. Conclusion

In the study, we evaluated the living environment, and we compared with the evaluation values and flood disaster risk. From the results of the analysis, we shows the some buildings are located at the flood disaster area. And the area with high *Eval* was included the flood risk area. These area has possibility of new development, so land use control is important.

In the future, we need to response heavy disaster caused by global warming. Infrastructure development is important method to protect our cities, but it takes a high cost and a long time. GI in Osato district is farmland and coastal pine forest. Land use control is important to keep the function of GI.

Osato district is depopulation city, so rapid urbanization will not occur. Therefore, it is important to promote new development for the east side of Osato and to control cluster farmland at the west side of Awa-kainan station and the west side of city hall.

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