Explore the Effect of Urban Flood with the Integration of Spatial Analysis Technique

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1 ABSTRACT

This study discusses the urban flood prevention spatial planning by utilizing the spatial analysis technique to investigate urban environmental feature and different urban flood issues happened in different location while facing the complicated coexistent relationship between urban flood. Typhoon Morakot in Tainan will be the case study. This study utilizes the Geographically Weighted Regression (GWR) to explore the variables of urban environment. The outcome may serve as basis for establishing future land-use indicators and as decision-making reference for concerned government agencies.

Key Words: Urban Flood, Geographically Weighted Regression , Land use plan

2 INTRODUCTION

In 2005, the World Bank issued Natural Disaster Hotspots – A Global Risk Analysis which indicted that Taiwan may be the most vulnerable to natural hazards place on earth, with 73 percent of population exposed to three or more hazards. Urban flood is a major compound disaster world-wide that causes serious loss to economic activities and impacts on urban activities severely. This study focuses on establishing flood index to explore the variables of urban environment that was considered as one of the most important aspects in regional flood-risk management.

Flood is among the most severe risks on human lives and properties, and has become more frequent and severe along with local economical development. As the Taiwan's city has been compact rapidly and more stress is put on the land to support the increased population. In turn, floods that once occurred infrequently during pre-development periods have now become more frequent and more severe due to the transformation of the watershed from rural to urban land uses and urbaniziation phenomenon is one of the main research topics in the last decade. A comprehensive plan addressing flood hazard management is therefore, necessary. This plan should combine land use strategies for each zone with the careful consideration of certain structural controls. This can be achieved by the minimal disruption of natural environments. These strategies could serve as basic components in a comprehensive flood management plan in Taiwan.

Therefore, the important issue is integrating spatial analysis technique to investigate urban environmental feature and different compound disaster issues happened in different location with complicated coexistent relationship between urban and disaster. The GWR Model was a popular method that applied to modify the flood problem (Brunsdon et al., 1996; Fotheringham et al., 1998; Platt, 2004; Zhang et al., 2004; 2005; Kupfer and Farris, 2007). Although this approach can incorporate more factors as the predictors and improve the statistical significance of the fitting model, it also increases the difficulty of date collecting for predictors to predict the damage in the future. Since flood damage is affected by many factors, some multiple regression models to incorporate such factors were also proposed.

This paper begins by reviewing pertinent literature regarding spatial pattern in assessing urban flood. Next, a GIS flood grade system integrates into the research to enhance the effectiveness and precision of measurements. Thus, the aim of this study is to establish the flood for flood shape area by using the smallest possible number of independent variables, while considering the spatial variation and solving the problem of spatial autocorrelation in residuals.

3 METHOD

The following equation expresses the relationship of the flood spatial autocorrelation, geographically weighted regression, and data from study area:

3.1 Spatial Autocorrelation

Similar objects in proximity to one another are positively spatially auto correlated, and vice versa, zero autocorrelation occurs when attributes are distributed independently in space. Moran's I, as expressed in equation 4, 5.

$$I(d) = \sum_{i} \sum_{l} w_{il} z_i z_l / S_0 m_2 \quad (1)$$

Where

$$S_0 = \sum_{i} \sum_{l} w_{il}, \quad m_2 = \sum_{i} z_i^2 / I \quad z_i = x_i - \bar{x} \quad (2)$$

A weight matrix has elements representing the connections in a set of spatial unit . The may assume any value, but in this paper we shall confine ourselves to a binary weight matrix consisting of ones (connected) and zeros (not connected). The diagonal elements of are zero. The variable is mapped onto the spatial units. The spatial autocorrelation analysis coefficient, Moran's I, is is the value of equity for each zone. i =1,2,. . ., I .

3.2 Geographically Weighted Regression

If the residual has spatial autocorrelation, then GWR can be utilised to modify the OLS regression to solve the problem (Brunsdon et al., 1996; Fotheringham et al., 1998; Platt, 2004; Zhang et al., 2004; 2005; Kupfer and Farris, 2007; Chang, 2008). If the spatially varied characteristics in flood are taken into account, equation 6 can be modified as:

$$y_i = b_0(\mathrm{u_i}, \mathrm{v_i}) + \sum_{k=1}^{n} b_k(u_{i,} v_i) \cdot X_{ik} + \varepsilon_i \ (3)$$

where: y_i is the flood of point i; x_i is the flood shape area of point i ; $u_{i,} v_i$ is the coordinates of the $\boldsymbol{i}$ point in space; b_0 ($u_{i,} v_i$), b_k ($u_{i,} v_i$) is the realization of the continuous function at point $\boldsymbol{i}$; ε_1 is the residual of point ($u_{i,} v_i$).

3.3 Data and study area

Located in the southeastern corner of Eurasia Taiwan sits in the middle of the Western Pacific festoon of islands. It faces the East China Sea to the north (600 km from the Ryukyu archipelago), the Bashi Channel to the south (350 km from the Philippines), the Taiwan Strait to the west (averaging 200 km from the Chinese mainland), and the Pacific Ocean to the east. Situated at the western rim of the Pacific Basin, the island plays an important role as an East Asian crossroad.These study area Tainan is the forth-grade city in Taiwan, but it's the oldest city which has abundant cultural heritage, as the cultural style presented. The methodology will now be described in greater detail, taking as an example its pilot application for Tainan in Taiwan, which is a town in which there is present risk from flood hazard. The extent of the flooding suffered by the inhabitants of Tainan in 2009 is illustrated in Fig. 2.

Fig. 2. Tainan, Taiwan, in the floods of Auguster 2009(source: http://www.flickr.com/photos/kyo4890x115/3807860280/)

4 RESULTS

4.1 Explore spatial data analysis of flood area

This paper through a cases studies in where natural hazard happened areas and the analysis used the data from Tainan in 2009. The method integrates GIS techniques, spatial autocorrelation analysis (SAA) and local indicators of spatial association (LISA) to analyze the process of disaster scale and decision making is guided by examination which may vary from large regions. The disasters mapping of locations with significant LISA statistics, together with an indication of the type of local spatial association as given by the quadrants in the Moran scatter plot, provide the basis for a substantive interpretation of spatial clusters or spatial outliers. Show in figure 3.

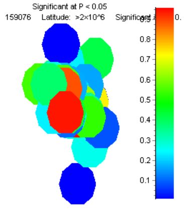
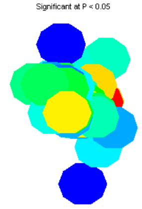
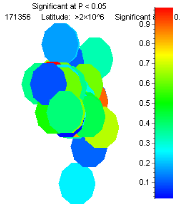
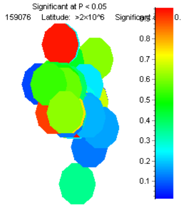
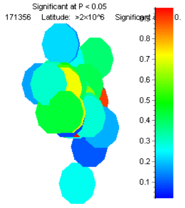
Flood Area	A	B	C	D	E
Explore spatial data analysis					

Fig.3 The SAA and LISA analysis

The result of the SAA analysis on Tainan the value of Moran's I is positive 0.52, and refers to the random and independent distribution in region. LISA provides information on the relative important of four types of spatial association: (1) high–high, high values (above the mean) associated with high risk values such as A, B D areas; (2) low–low, low values (below the mean) associated with low risk values; (3) low–high, low values associated with high risk values; and (4) high–low, high values associated with low risk values. In the future, the land use planning suggests strengthening prevention such as Yong Kang district, Sinying district and Madou district.

4.2 GWR model

The GWR model results were more closely examined in this study to develop fur¬ther knowledge for later use in modifying the traditional OLS regression model. The regression result is shown in Table 2.

Effective Number of Parameters	Correlation Coefficient (r)	Coefficient of Determination (r^2)	Adjusted r-square (r^2 Adj)	P-valu
7.39	0.33	0.109	0.109	0.046(*$p<0.05$)

TABLE 2 Global regression parameter estimates (nis37)

The coefficient of determination is 0.109 while the residuals plot is shown as in Fig. 2. The application of GWR model improved the increased from 0.36, demonstrating that GWR provides a better interpreting ability than OLS. As shown in Fig. 4, the histogram of intercept estimates displays three obvious groups. Figure 6 depicts the spatial distribution of these three groups. There is a significant clustered pattern indicating that basic flood shape area increase gradually from west to southwest corner in the study region shown in fig.5. These parameter estimates indicate the change of the flood with the flood shape area, and are increased gradually from west to northwest in the study area.

4.3 Land use and flood analysis

The analyses of land using and flood herein cover comparisons of area size and land using category in Tainan City. In addition to interpreting the results of previous analyses of land using and flood in broad views, we predict that land using under limited control resources has some impacts to the flood.

Flood	Land Using Category	Total area(ha)	Number	Mean	S. dev.
High	Agriculture	1,254.6	729	1.72	5.61
	Building Area	1,40.2	1,290	0.10	0.71
	Green Space and Park	9.9	30	0.33	0.63
Medium	Agriculture	5,572.6	7,680	0.72	2.49
	Building Area	1,017	9,223	0.11	0.66
	Green Space and Park	4,549.7	193	0.23	0.76
Low	Agriculture	514.9	1,324	0.38	1.67
	Building Area	713.9	7,296	0.09	0.58
	Green Space and Park	128.5	233	0.55	1.25

TABLE 3 The descriptive statistic of flood

In Tainan City, 1,254.6 hectares of agriculture area were damaged because of high flood. Green space and park were not enough to absorptive capacity in the high flood area over 9.9 hectares. The highest capacity which green space and park can be absorptive in the Medium flood area is about 5,572.6 hectares. In the past, land use and flood analyses have been used to represent the size qualities of land use category. The land use and flood are affected by population, land using construction, and local differences. The construction of land using is often related to the geographic environment and urban development that mainly influences urban flood intensity.

5 CONCLUSTION

The paper proposed an approach that not only uses the smallest numbers of explained variables to establish the flood functions for flood shape area, but also solves the problem in traditional regression models by overlooking the spatial variations with flooding loss characteristics.

The introduction of the GWR model improved the coefficient of determination from 0.36 in the original OLS to 0.109. The GWR model corrects the spatial autocorrelation problems in residuals with some drawbacks still. It produces a different set of estimates for the regression parameters at each sample points. On the other hand, the results of flood and land use analyses indicate the three level risk of flood within land using situation, taken the urban flood characteristics of spatial pattern into consideration to improve green space and urban park area, and land using capacity that supplements urban environment safety and sustainable development.

6 REFERENCES

Brunsdon, C., A. S. Fotheringham, and M. E. Charlton. 1996: "Geographically weighted regression: A method for exploring spatial nonstationarity." Geographical Analysis 28:281-298.

Chang, L. F., C. H. Lin, and M. D. Su. 2008: "Application of geographic weighted regression to establish flood-damage functions reflecting spatial variation." Water Sa 34:209-215.

Feng, L. H. and G. Y. Luo. 2010: "Proposal for a quantitative index of flood disasters." Disasters 34:695-704.

Fotheringham, A. S., M. E. Charlton, and C. Brunsdon. 1998: "Geographically weighted regression: a natural evolution of the expansion method for spatial data analysis." Environment and Planning A 30:1905-1927.

Kupfer, J. A. and C. A. Farris. 2007: "Incorporating spatial non-stationarity of regression coefficients into predictive vegetation models." Landscape Ecology 22:837-852.

Platt, R. V. 2004: "Global and local analysis of fragmentation in a mountain region of Colorado." Agriculture Ecosystems & Environment 101:207-218.

Zhang, L. J., H. Q. Bi, P. F. Cheng, and C. J. Davis. 2004: "Modeling spatial variation in tree diameter-height relationships." Forest Ecology and Management 189:317-329.

Zhang, L. J., J. H. Gove, and L. S. Heath. 2005: "Spatial residual analysis of six modeling techniques." Ecological Modelling 186:154-177.