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FLOOD DAMAGE ASSESSMENT OF YIZHUANG, BEIJING

Yuwen Zhou[1,*], Zilong Liu[1], Shanshan Liu[1], Jian Zhao[1], Wei Li[2], Jing Zhang[2], Albert S. Chen[3]

[1] Beijing University of Technology, China, [2]Hebei University of Science and Technology, Shijiazhuang, China
[3] University of Exeter, UK
[*] *College of Architecture and Civil Engineering, Beijing, 100124; Tel: +86 010 67395614; E-mail: liu360313@126.com*

ABSTRACT

Based on hazard analysis, exposure analysis and vulnerability analysis of urban local flooding, this research demonstrates the approach of building content damage assessment methodology. Through the case study of Beijing Yizhuang, it describes the underlying data and basic processes for loss calculation. Due to the lack of depth-damage curves of Beijing, the present results are at this stage preliminary. More accurate loss calculations require further basic data collection and local depth-damage curve construction.

KEYWORDS
Urban local flooding; damage assessment; hydraulic model; GIS

1. INTRODUCTION

Flood damage is defined as the potential loss resulting from hazard analysis, exposure analysis and vulnerability analysis. More specifically, the extent of the losses depends on the intensity and probability of the hazard, the exposure of the assets, objects, or people, and their fragility or sensitivity. Flood damage assessment in urban areas has become a major issue that the international research community has placed great attention, which simultaneously lays the foundations and provides valuable references for proposing and implementing hazard prevention and mitigation strategies (Dilley et al, 2005).

The hazard and bearing bodies are the two primary elements taken into account in the loss quantification process. Typically, hydraulic modelling is adopted to capture the hazard properties, which typically includes the flooded depth, extent, duration and discharge, together with bearing body raster file and vulnerability information to realise flood loss evaluation under various hazard conditions. This paper introduces the approach of deriving building content damage in urban local flooding events, and demonstrates its feasibility through GIS spatial-based analysis tool to carry out the Beijing Yizhuang case study.

2. METHODOLOGY

2.1 Pluvial flooding in urban area

Pluvial flooding happens when the rainfall surpasses the drainage capacity of urban drainage network, and the excess amount of water accumulates on the surface. The flood damage is commonly classified as tangible and intangible (Merz et al, 2010). The former could be quantified as specific numerical values which mainly involves the loss of infrastructure, building and engineering structures. While the latter one focuses the impacts on residence health, environment and public psychology without regular indicators for analysis.

According to the contacting pattern between bearing body and flood, the tangible damage is futher categorised as direct and indirect loss. Direct loss, which is caused by physical contact between these two elements, is expressed as the loss of residential building, indoor properties and commercial and industrial stock. While indirect loss refers to influence due to delay of production, delivery of industry, commerce and tertiary industry owning to economic activity termination (Li, 2007). The core content of this research emphasises the direct loss from tangible classification.

2.2 Damage assessment approach

Flood damage evaluation typically compasses four steps: hazard analysis, bearing body exposure assessment, vulnerability analysis and loss quantification. Firstly, hazard analysis that acquires information such as indictor intensity, frequency and scope for hydraulic modelling of scenarios has become the mainstream approach (Gambolati et al, 2002). The premise for constructing urban flooding model is to gather detailed information of drainage networks, rivers, flood defence and structures, topography and rainfall, most of which could be achieved by remote sensing analysis and site survey. Based on a series of hydrology and hydraulic principles, we simulated the physical process of pluvial flood using a numerical model for events with different probability to obtain hazard indicators variation over time and space.

Secondly, through socio-economic survey & statistics and geospatial information database, the exposure assessment takes advantage of area weighting method to derive spatial attributes of socio-economic condition, thereby reflecting spatial distribution difference in the economic indicator of bearing body. Lastly, vulnerability analysis, usually represented by depth- damage curve, relies on the typical sampling survey to establish statistical relationship between hazard and economic losses factors (Smith, 1994). In view of above statement, the flood damage assessment procedure is demonstrated in Fig 1:

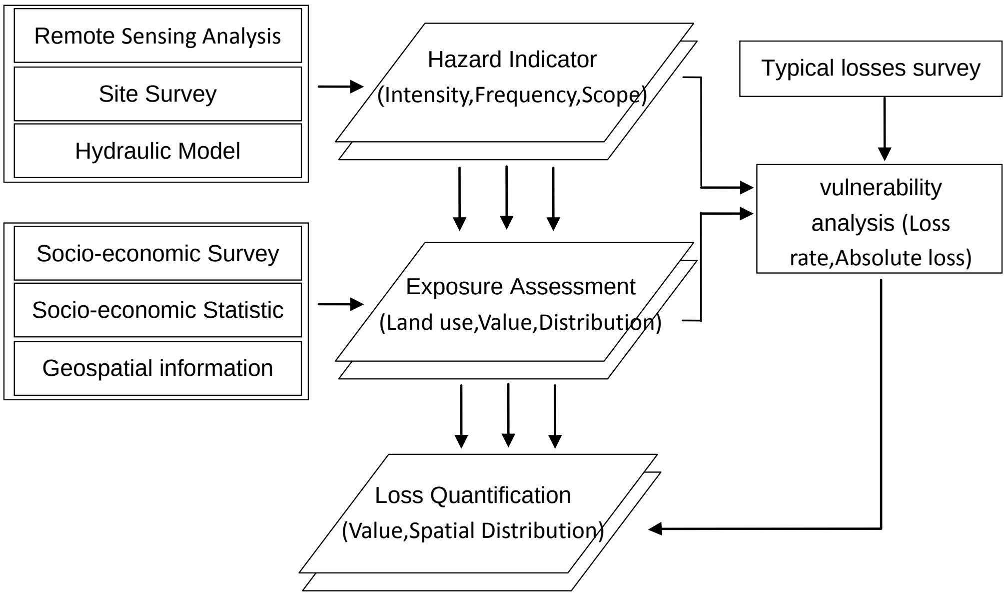

Figure 1. Flood damage assessment procedure

The vulnerability expression could be identified as relationships between hazard and loss rate or absolute loss value. The depth-absolute loss vulnerability curves of various types of assets have been set up in large amount of developed countries (Penning Rowsell et al, 2010), but the loss rate is more preferred in China. In fact, these two approaches just differ slightly in expression manner but with same essence. Due to the association between the building land use type and loss rate, the following formula is generated to calculate flood damage.

$$L = \sum_i \sum_j L_{ij} \sigma(i, j) \quad (1)$$

Where L is total flood loss, L_{ij} is loss value of property category i at depth j, σ (i,j) is the loss rate of property category i at depth j.

3. CASE STUDY, BEIJING YIZHUANG

The case study area Yizhuang is a newly developed town to the southeast of Beijing city central region. The specific location is north latitude 39°45'-39°50', east longitude 116°25'-116°34', with the distance of 17.6km to the Tiananmen Square. The total area is 212.7km^2, as shown in Fig 2, which includes the Beijing Economic and Technological Development Zone in the Daxing District), the Tongzhou, and the western part of Chaoyang District.

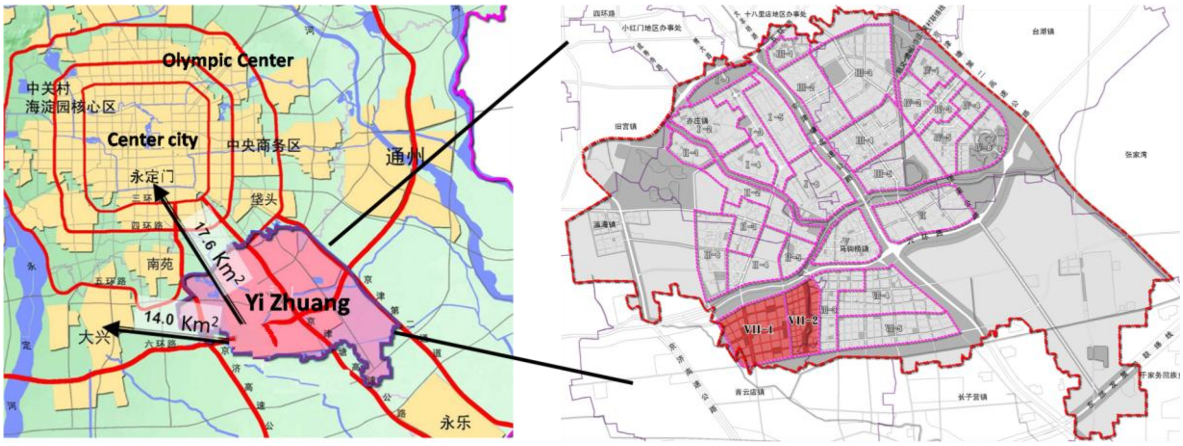

Figure 2. Specific location of Yizhuang

Yizhuang has a flat terrain with average altitude between 26-34m. The overall topography is sloping down from the northwest to the southeast with gradual slope between 1/1000 and 1/2500, which is defined as piedmont plain type. The averaged rainfall is approximately 539.4mm with high seasonal. The rainfall concentrates in months between June and September, accounting for 83.3% of the annual precipitation. According to the history record, the maximum annual rainfall was 928.9mm for the period between 1956 and 2000 and corresponding minimum annual precipitation was 318.6mm.

In 2005, Yizhuang had 232.8 thousands inhabitants, increasing 104.1 thousands in 2001, and the population kept growing rapidly and reached 700 thousands in 2012. Until the end of 2003, the numbers of enterprises in this economic and technological development zone was accounted to 1383 with total investment over 6 billion RMB. With the advancement in last two decades, this region has formed five pillar industries with high economical productivity, which consist of electronic information, optical-mechanical-electrical integration, bio-engineering and new medicine, new energy and new materials and software manufacturing. From the socio-economic aspect, Yizhuang as the high-tech industrial zone, is the region where great emphasis of flood damage assessment research should be placed.

3.1 Data required

The data required for flood damage assessment comprises four basic aspects: input data for drainage model, hydraulic modelling result, building data, and building vulnerability information. The details are explained as following.

(1) Basic data for hydraulic model

Pipe network data, ground elevation data and rainfall information are three essential components for hydraulic model. The drainage network data includes topology structure of pipe, pump station, relevant hydraulic facilities and other hydrology and hydraulic parameters. The surface information contains catchment processing parameters and ground digital elevation model, for which 10m*10m regular grid was used for the following case study. The rainfall information is the input for 1D network modelling, combined with Beijing annual maximum storm intensity formula and 24-h hydrological hyetograph to generate design rainfall for various return periods (Zhou, 2011).

Relative sound separated drainage system has been constructed in Yizhuang region with total length of 183km, the design standards for return period is between0.5 to 1 year. Regional pipe network distribution is displayed in Fig 3(a) according to the sizes.

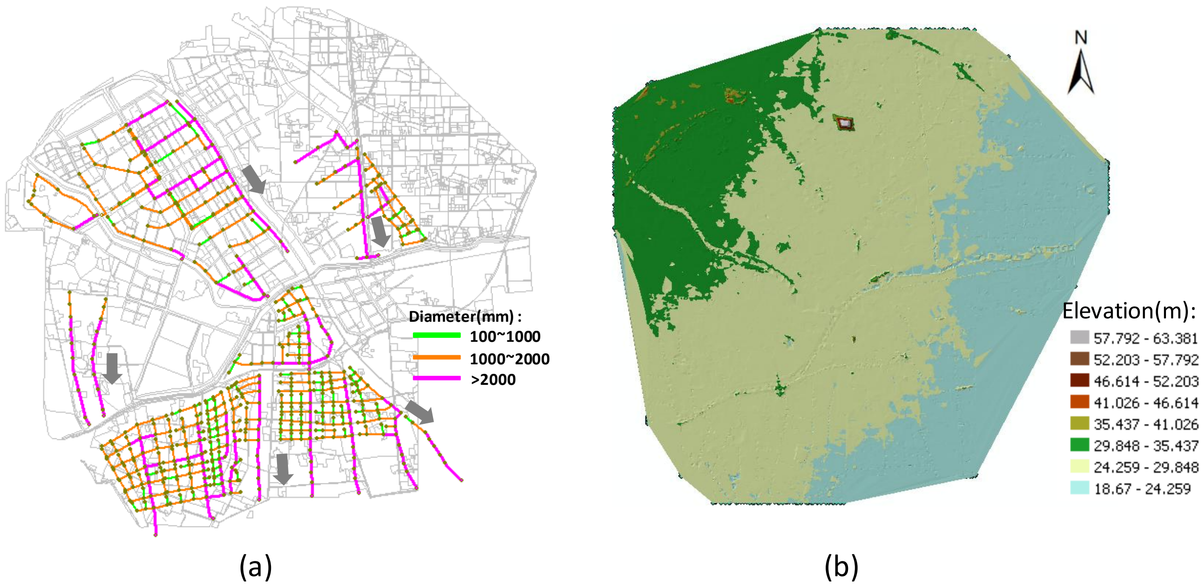

Figure 3. Hydraulic model basic data. (a): Regional pipe network; (b): DEM model

Based on the surveying and mapping elevation database of Beijing(latitude, longitude and elevation as main attributes), inverse distance weighted interpolation tool under 3D Analyst Modules is applied to constructing DEM model with resolution of 10m*10m(refer to Fig 3(b)).

The rainfall distribution over time derived by the combination with Beijing annual maximum storm intensity formula (Formula expression 2) and 24h design rainfall pattern is shown in Fig 4.

$$i = \frac{12.267(1+0.913\log P)}{(t+13.4)^{0.725}}(mm/\min) \tag{2}$$

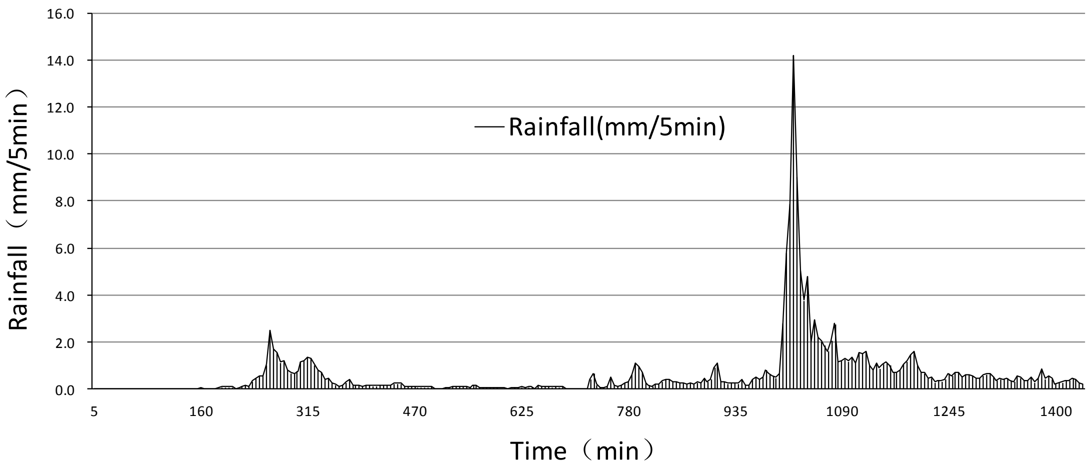

Figure 4. 24h rainfall pattern of Beijing (ten years return period is shown)

In practice, the first step is to calculate the rainfall with different duration and specific return period through the storm intensity formula shown in expression 2. Then, the rainfall multiplied by the proportion which is show in 24h allocation table (Table 1) to get each 5-minute rainfall. As a result, the maximum rainfalls with various durations have a unified return period.

Table 1. 24h allocation table of design rainfall pattern.

Times（min）	5	…	1010	1015	1020	1025	1030	1035	…	1440
Proportion of H5					100%					
Proportion of (H15-H5)				46.67%		53.33%				
Proportion of (H30-H15)			39.69%				34.55%	25.76%		
Proportion of (H45-H30）										
Proportion of (H60-H45)										
Proportion of (H90-H60）										
Proportion of (H120-H90)										
Proportion of (H150-H120)										
Proportion of (H180-H150)										
Proportion of (H240-H180）										
Proportion of (H360-H240)										
Proportion of (H720-H360）										0.79%
Proportion of (H1440-H720)	0%									

(2) Hydraulic modelling results

We adopted the DHI MIKE URBAN software, which couples the 1D drainage network model and the 2D overland flow model (DHI Water, 2009), to simulate the inundation circumstances for different return periods. Detailed spatial distribution of submerged water depth for 10, 20, 50, 100 year return period events are demonstrated in Fig 5:

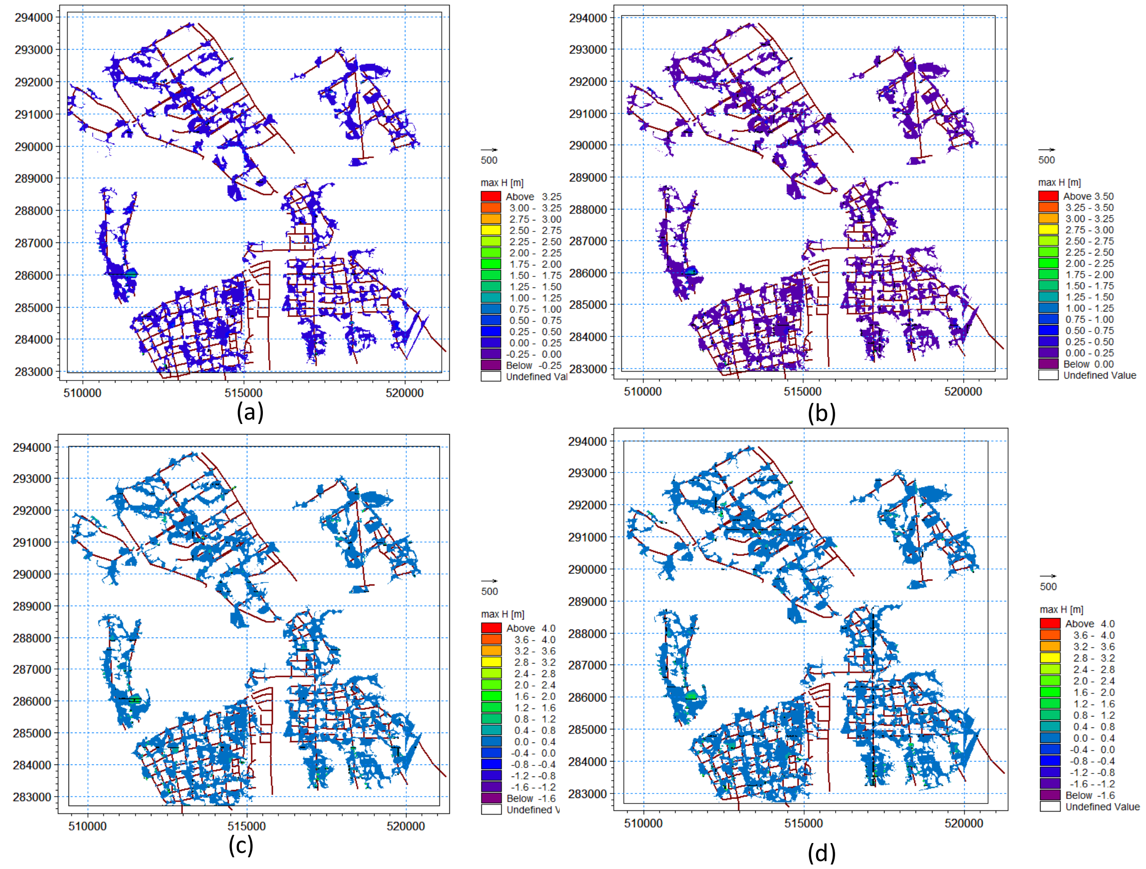

Figure 5. Spatial distribution of inundation for (a) 10, (b) 20, (c) 50, and (d) 100 year return period events.

(3) Building vector data

Unique index value is introduced to distinguish building vector data, which could be overlapped with land use maps to generate building land use spatial distribution (Fig 6).

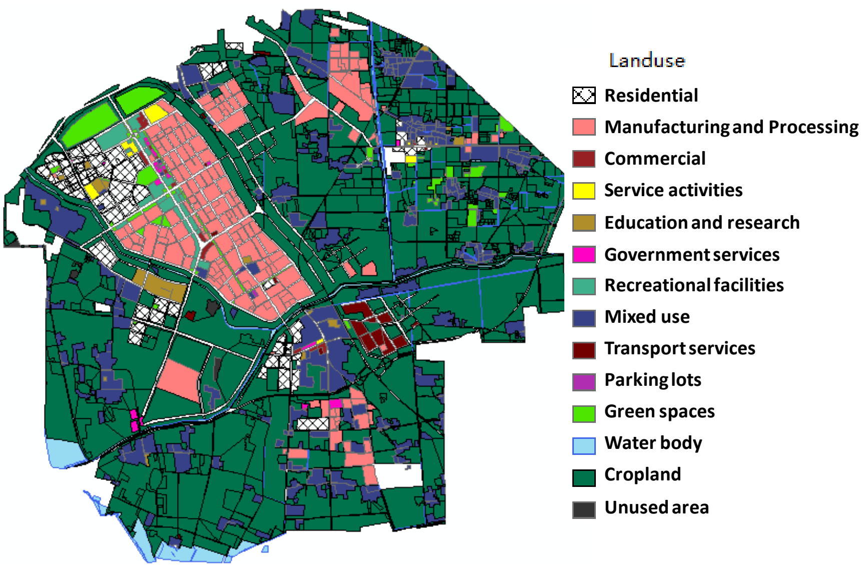

Figure 6. Building land use spatial distribution.

(4) Building vulnerability data

Due to the lack of the depth-damage relationship in Beijing, we applied 10 depth-absolute damage curves, developed by Penning-Rowsell et al. (2010) for the UK, to describe the vulnerability of different land use types for preliminary testing in the study. The specific information is displayed in Fig 7.

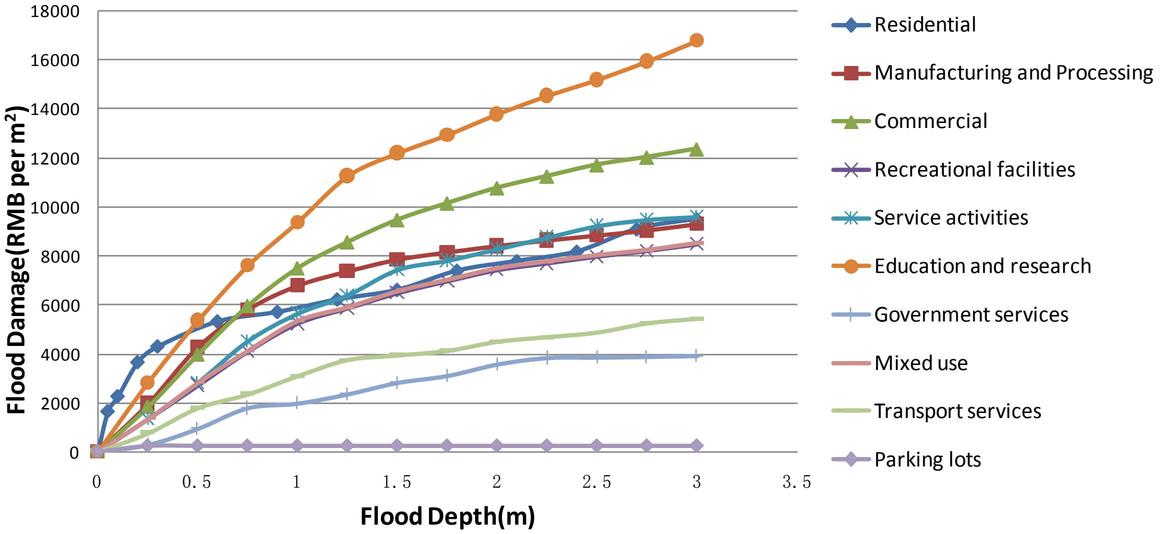

Figure 7. Depth-absolute damage curve of UK.

3.2 Damage results

We developed a flood damage assessment tool using Python scripts and the Geo-processing functions within the ESRI ArcGIS software, to evaluate the damage directly from the hydraulic modelling results. This tool is capable of exerting flood damage calculation and risk analysis with spatial properties at single building scale (Fig 8). The flood damage statistics is summarised in Table 2.

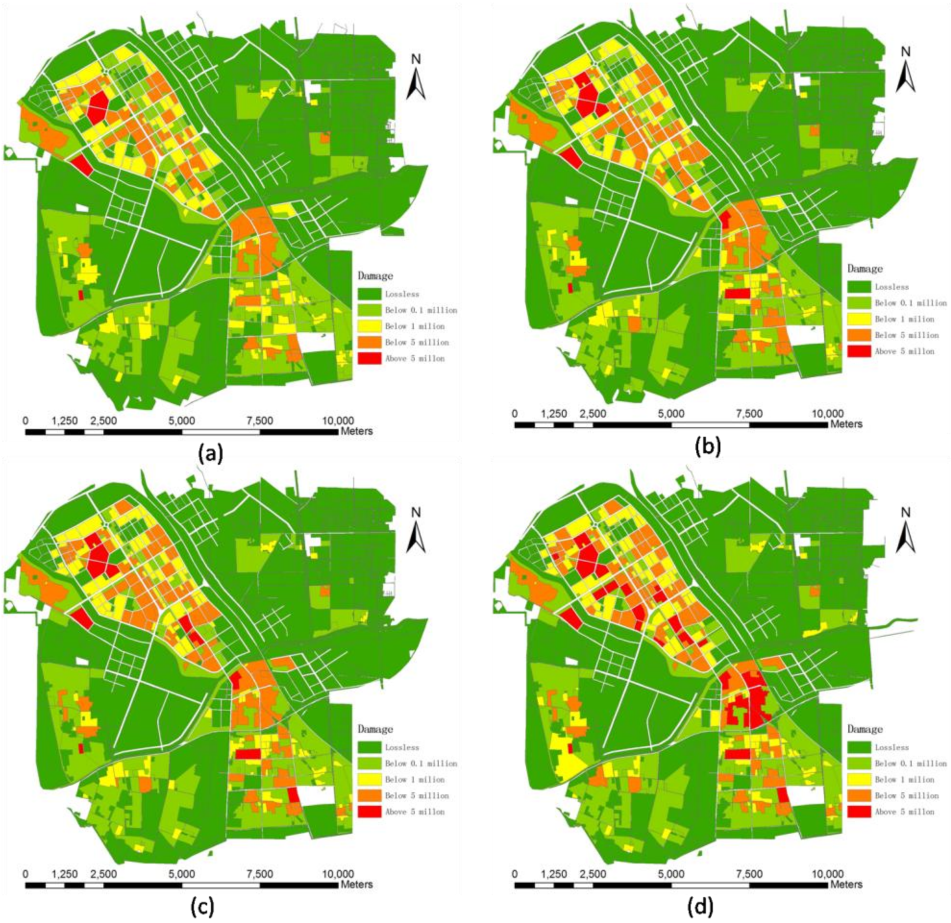

Figure 8. Building damage results of (a) 10, (b) 20, (c) 50, and (d) 100 year return period events.

Table 2. Flood damage and rainfall statistics for different return period.

Return period (year)	10	20	50	100
Rainfall(mm)	172	197	229	254
Total Loss (million RMB)	201	323	497	590

Note: RMB means Chinese Currency which calculated by currency exchange rate between RMB and GBP (1:0.1065).

The relationship of flood damage versus design storm frequency is shown in Fig 9:

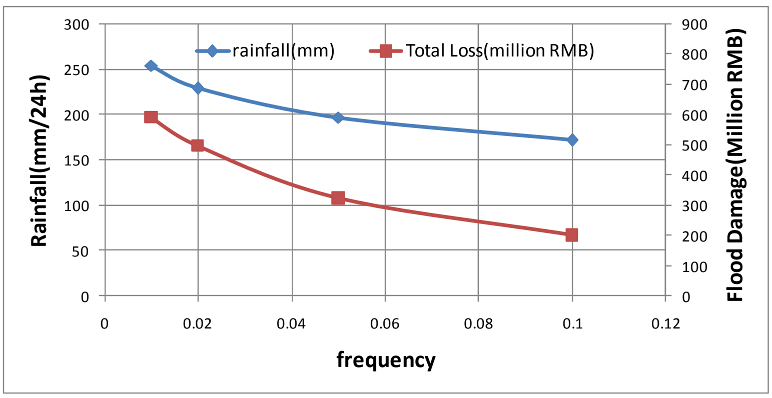

Figure 9. Relationship of flood damage versus design storm frequency.(Note: the frequency is for the total rainfall, as the maximum rainfall with different durations have the same return period.)

4. CONCLUSION

Based on hazard analysis, exposure analysis and vulnerability analysis of urban pluvial flooding, we demonstrated the approach of building content damage assessment and risk quantification methodology. Through case study of Yizhuang, we explained the required input data, which mainly includes basic input and simulation results of hydraulic modelling, , building data and vulnerability information. We developed a GIS-based damage assessment tool that integrates all the above elements and achieves the economic loss quantification. The case study provided valuable reference for damage evaluation during urban local flooding events.

Compared with previous experienced indicators-based assessment approach, the proposed approach can provide more detailed information about building damage due to flooding. However, due to the lack of depth-damage curves of Beijing, we adopted the DDCs from literature for the preliminary modelling. In the future, the construction of flood damage database for Beijing would be critical for reliable flood damage assessment.

5. ACKNOWLEDGEMENTS

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