Measuring Recovery to Build up Metrics of Resilience to Flash Floods Based on Pollutant Discharge Data: A Case Study in East China

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1 | Introduction :

Motivations & Challenges & Highlights

I Introduction

Increasing Attentions on Disaster Resilience, especially area vulnerable to natural hazards.

Motivations

Challenges

Highlights

I Introduction

Increasing Attentions on Disaster Resilience, especially area vulnerable to natural hazards.

Motivations

- Frequent flash floods in China
- Call for resilience development
- Antecedent resilience condition affects the post-disaster recovery process
- Use recovery measurement as an external term to validate the resilience metrics and identify the dominant factors of local resilience

→ How to measure recovery capability ? !

I Introduction

Increasing Attentions on Disaster Resilience, especially area vulnerable to natural hazards.

Challenges

- Short-term recovery after flash floods
  - X Long-term: population increase
  - X Weather condition: Optical RS images
  - X Cost-efficiency: Radar data
- Proper recovery indicators: refunctioning of people’s lives and livelihoods more than receding of floodwater

I Introduction

Increasing Attentions on Disaster Resilience, especially area vulnerable to natural hazards.

Highlights

- **A new approach to measure recovery capability based on pollutant discharge data**
- **Enterprises with heavy pollutant discharges are required to disclose the records of pollutant discharge per hour online**
- **A chance to detect the disturbance caused by flash floods → minitor recovery process**

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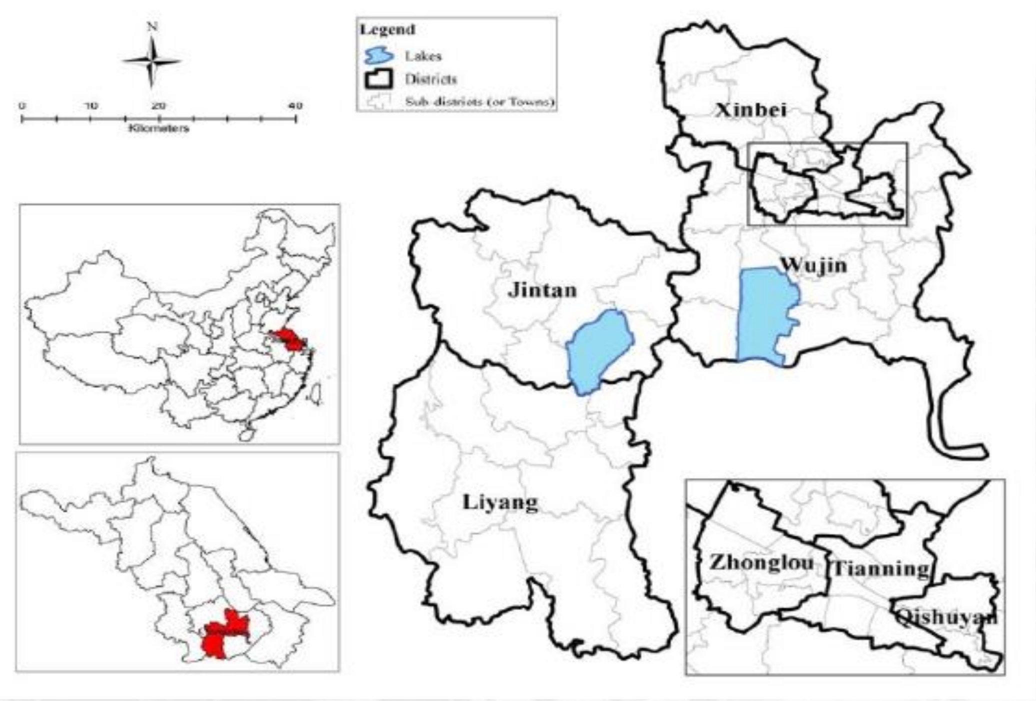
2 | Methodology:

Study Area & Framework & Procedures

I Methodology

Study Area: Changzhou City, Jiangsu Province of China



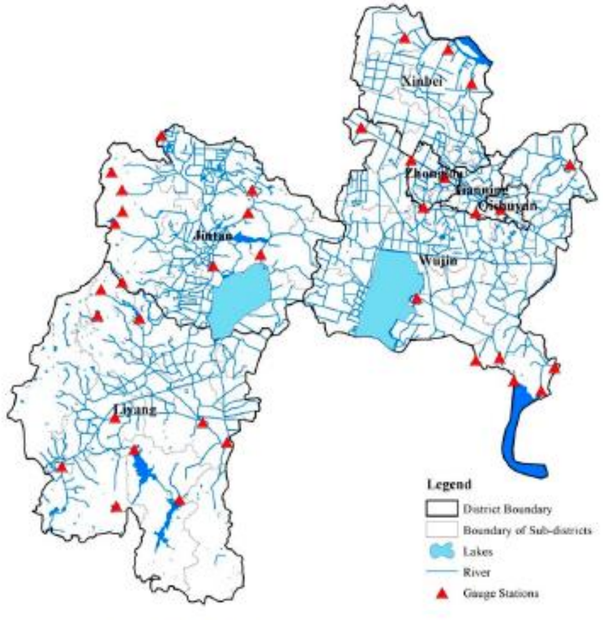


Figure 4. Distribution of gauge stations.

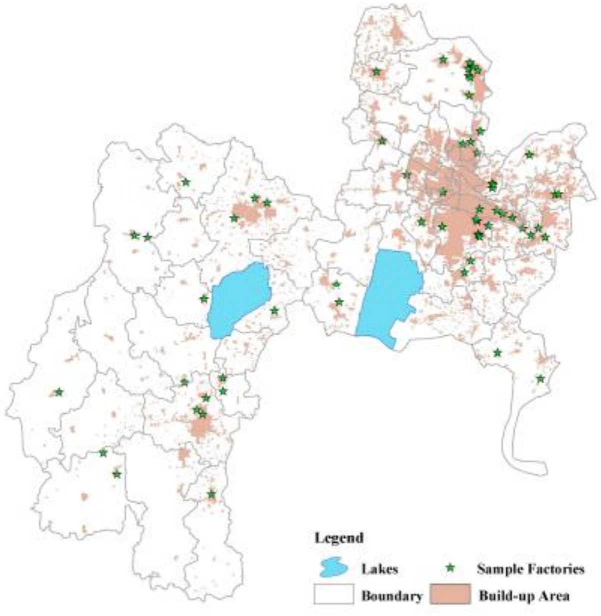


Figure 2. Monitoring points of sample enterprises.

Record-breaking

- ✓ Worst flood in 600 years;
- ✓ Affect over 65,000 people; Cause 410 million RMB loss;
- ✓ New national precipitation record of 247 millimeters in 24 hours

Data availability

- ✓Records from rain gauge stations
- ✓Hourly waste water and gas emission data published online
  <-- Ministry of Environmental Protection of China

I Methodology

The Whole Framework

- Measure Recovery Capability

✓Data Preprocessing

✓Change Detection

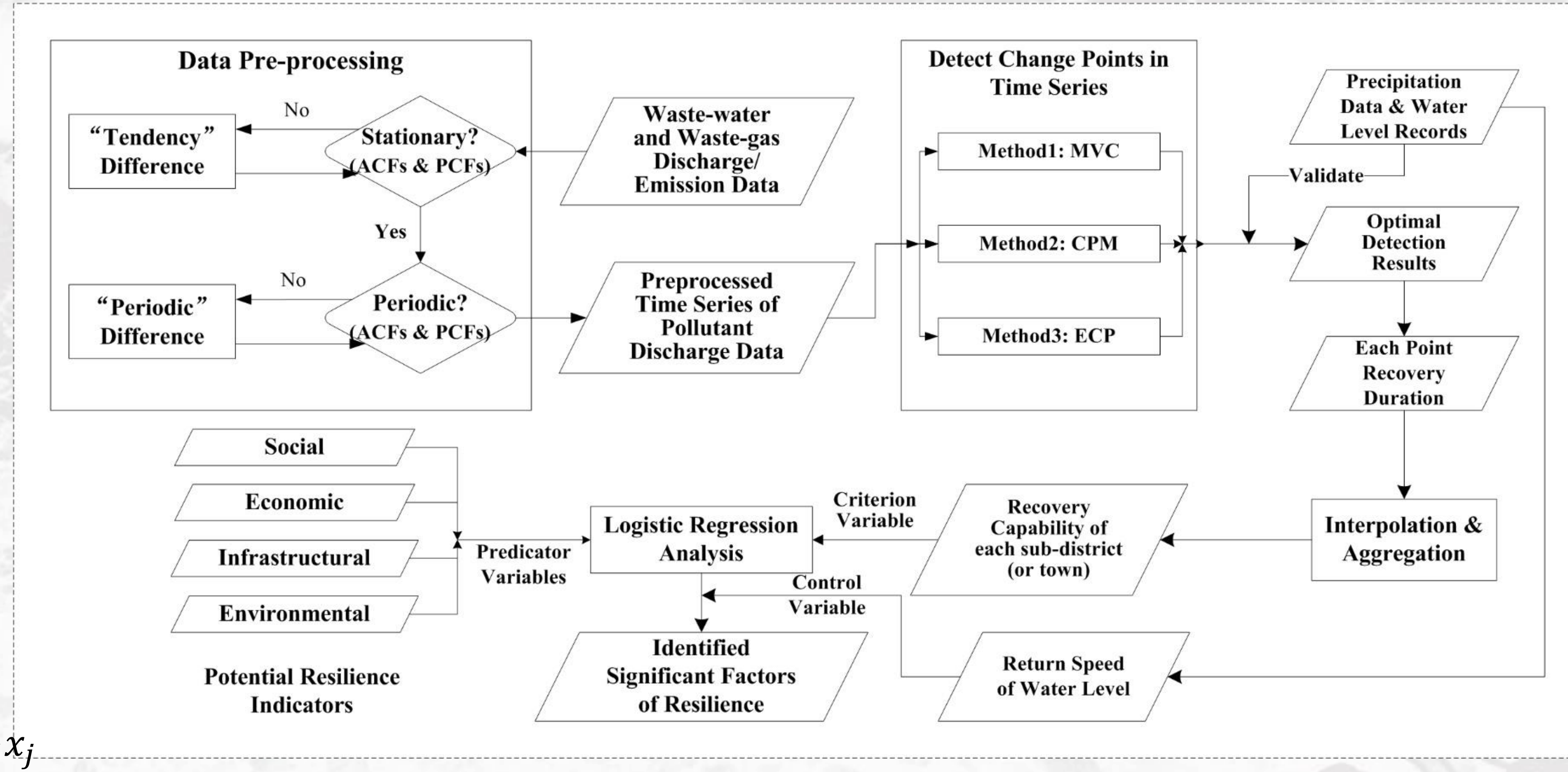
✓Optimize Detection Results

- Validate Metrics of Resilience

✓Select Potential Indicators

✓Logistic regression:

$$\log\left(\frac{P(Y = k_i)}{P(Y = K)}\right) = a_i + b_{i1}x_1 + b_{i2}x_2 + \cdots + b_{ij}x_j$$

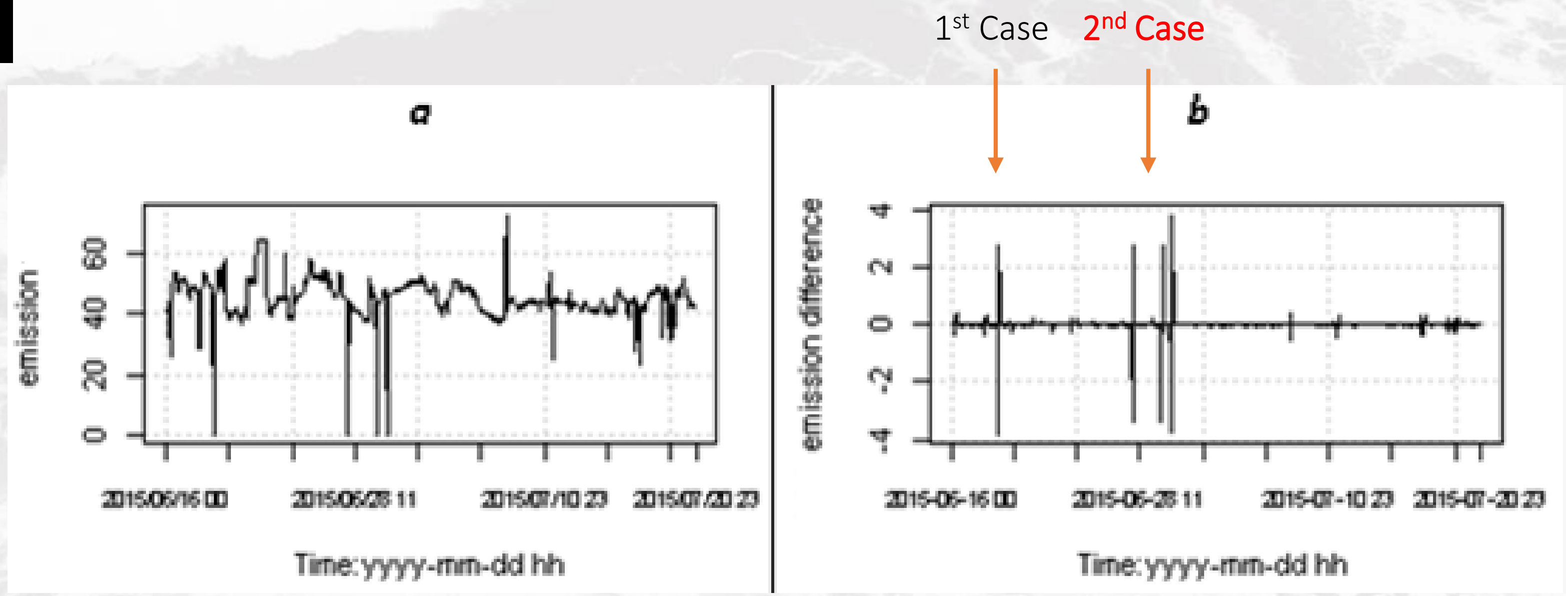


I Methodology

Pollutant Discharge Data is Very Sensitive to Flood Disturbance!

Preprocessing of Pollutant Discharge Data

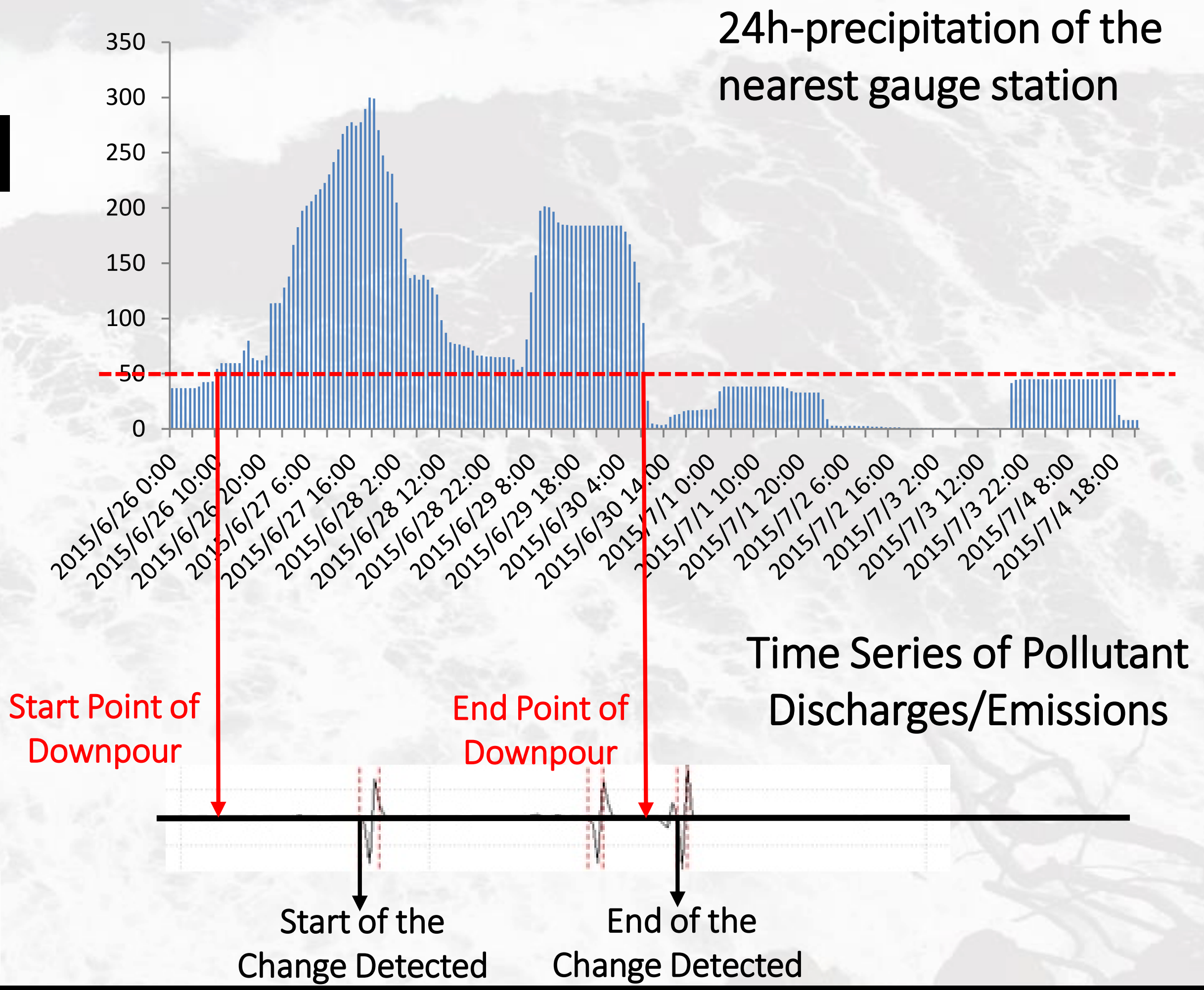
- ✓ Eliminate the tendency and periodicity of time series: (the first difference with 1-cycle lags)
- ✓ Achieve a stationary and independent series over time



I Methodology

Detect Change Points in Pollutant Discharge Time Series Data

- **DOWNPOUR:** the degree of rainfall reaches downpour level if over 24 h precipitation accumulation exceeds **50 mm** and tends to continue (the Chinese precipitation classification system).
- **Assumption:** if the sample enterprise or its surrounding areas are inundated, its pollutant discharge records will be disturbed (changes **START**) during the downpour and recover (changes **END**) after it.
- **START POINT:** the first immediately after the time of the **FIRST** downpour record of its **NEAREST** rain gauge station.
- **END POINT:** the first of the alternatives immediately after the time of the **LAST** downpour record, as observed by its nearest rain gauge station.
- $$D_{Return}(i) = T_{End\ of\ Change\ detected}(i) - T_{End\ of\ Downpour}(i)$$



I Methodology

Compare and Optimize the Detection Results

- As the sample monitoring point demonstrates change **ONLY** when the sample area or the surrounding area is affected by the flood, we examined the final change detection results of sample enterprises with respect to the **flood-damaged area**.

- For this purpose 100 m buffers for each sample monitoring point were created and used to examine whether they **INTERSECT** with the damaged area.

- The detection accuracy is calculated following Equations (1) and (2), based on real situations (damage or non-damage) and detection results (change or non-change), as shown in Table 1.
- $r_{correct} = \frac{a+d}{a+b+c+d}$ (1) $r_{misdetect} = \frac{b+c}{a+b+c+d}$ (2)

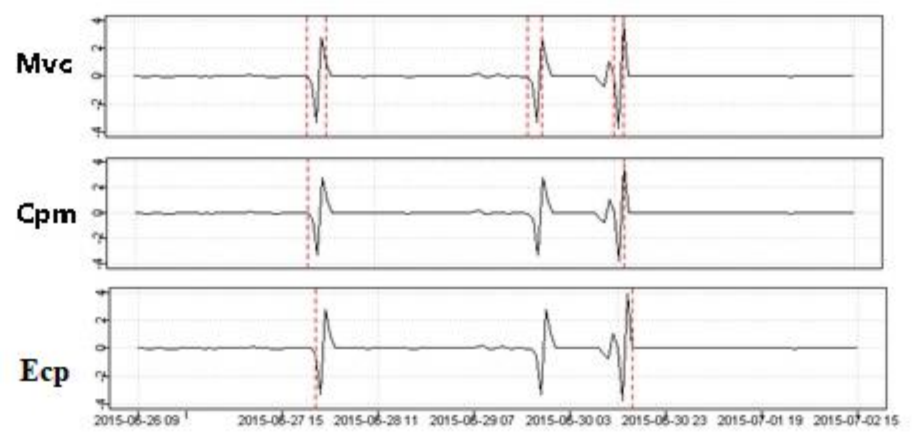


Fig. Sample results of three different methods: Multiple Changes in Variance of Cumulative Sums of Squares (Mvc, Killick and Eckley, 2014); Change Point Model (Cpm, Hawkin et al, 2003); Energy statistic-based Change Point Model (ecp, Szekely and Rizzo, 2005&2010).

Table 1. Comparison of Detection Results

Samples	Change	Non-Change
Damage	a	b
Non-Damage	c	d

I Methodology

Select and Validate Resilience Metrics

➢ **Potential Resilience Indicators:**

- Social
- Economic
- Infrastructural
- Environmental

➢ **Validate the Selected Indicators:**

- Calculate and Reclassify recovery capability based on the recovery duration
- Logistic Regression

$$\log\left(\frac{P(Y = k_i)}{P(Y = K)}\right) = a_i + b_{i1}x_1 + b_{i2}x_2 + \cdots + b_{ij}x_j$$

Table 2. Variables representing the four subcomponents of disaster resilience.

Sub-Component	Label	Variable	Measures	Data Source
Social Component	Age Distribution	Age	% population between 15 and 64 years old	PCC, 2010
	Sex Ratio	Gender	sex ratio (male/female)	PCC, 2010
	Health Services	Support of health facilities	population share of health facilities	PCC, 2010
	Non-household Population	Mobility of labor force	% non-household population	PCC, 2010
Economic Component	Ratio of Urban to Rural	Urban population	ratio of residents to villages	OSM, 2013
	GDP per Capita	Gross Domestic Product	Gross Domestic Product per capita	GCRD, 2010
	Share of CBD	Commercial establishment	Share of business (CBD centers) within build-up area	OSM, 2013
	Manufacturing Density	Manufacturing establishment	density of manufacturing within build-up area	OSM, 2013
Infrastructural Component	Road Density	Transport	road density	OSM, 2013
	Access to Open Space	Emergency preparation	access to open space (parks, urban green space, stadium, parking area)	OSM, 2013
	Access to Administration	Emergency preparation	access to governmental institutions (administration center, police station)	OSM, 2013
	Access to Hospital	Emergency preparation	access to hospitals	OSM, 2013
Environmental Component	DEM	Geological condition	mean of Digital Elevation Model (DEM) data	GDEMV2, 2009
	Slope	Geological condition	mean slope	GDEM SLOPE, 2009
	River Density	Land use in natural terms	density of water network	OSM,2013
	Urban Green Area	Green area within build-up area	total area of green space per square kilometer of build-up area	OSM, 2013

3

3 | Results & Analysis

Recovery Measurement & Identification of Significant Resilience Indicators

I Results & Analysis

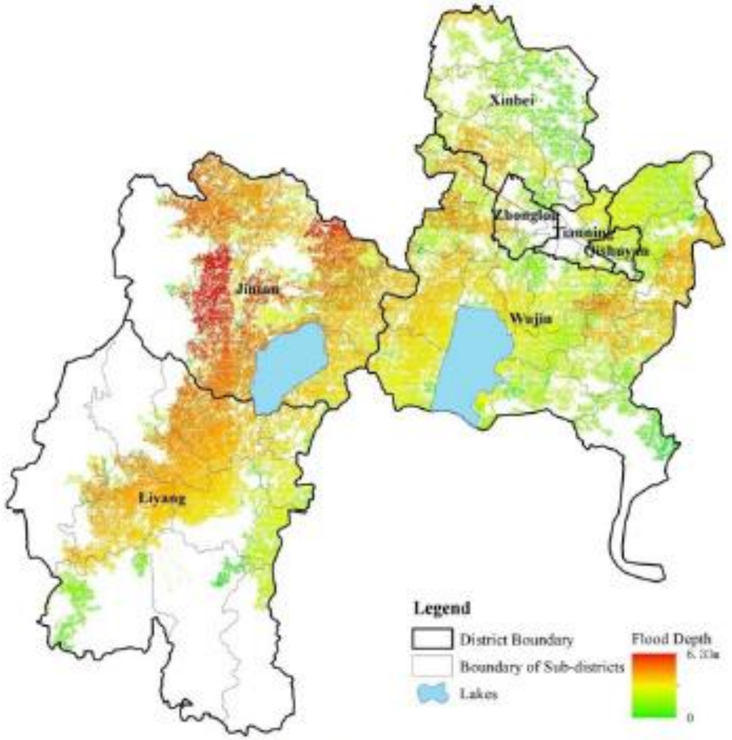


Figure 6. Flood inundation map.

Table 3. Detection results of the three methods.

Mvc	Change	Non-Change
Damage	28	18
Non-Damage	3	8
Cpm	Change	Non-Change
Damage	35	12
Non-Damage	8	2
Ecp	Change	Non-Change
Damage	35	11
Non-Damage	5	6

Table 4. Accuracy of detection.

Measure	mvc	cpm	ecp
Correct Detection Rate	0.63	0.65	0.72
Misdetection Rate	0.37	0.35	0.28

I Results & Analysis

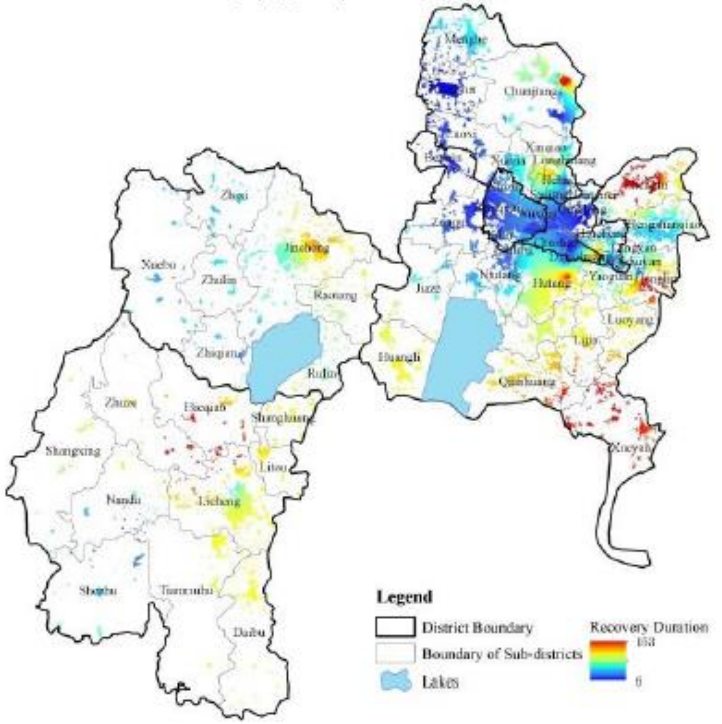


Figure 7. Time consumption for recovery within build-up area.

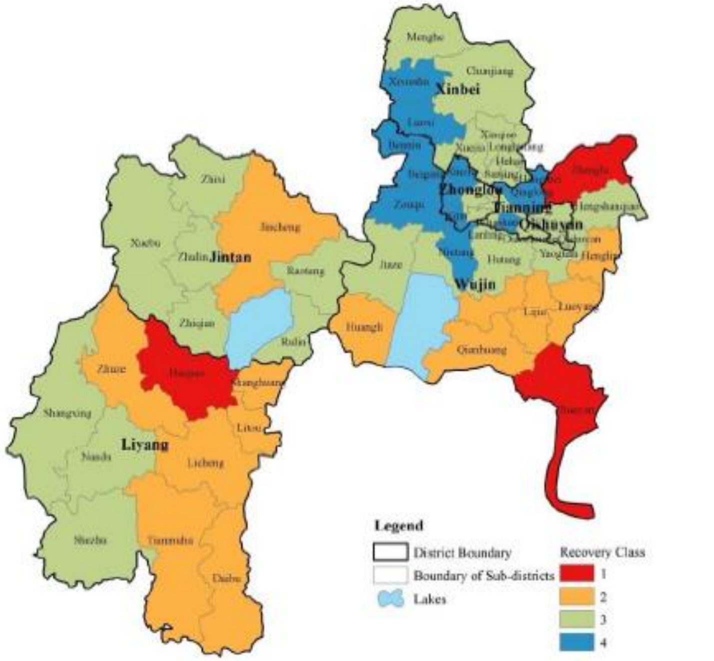


Figure 8. Recovery Class of each sub-district (or town): Class 4—high recovery capability; Class 3—moderate to high recovery capability; Class 2—moderate to low recovery capability; Class 1—low recovery capability.

I Results & Analysis

Table 5. Regression results of potential variables.

Component	Variable	Estimate	Significance (Two-Tailed)
Social	Sex Ratio	1.074	0.050 *
	Health Service	1.219	0.043 *
Economic	Ratio of Urban to Rural	1.393	0.044 *
	Share of CBD	—	—
Infrastructural	Road Density	3.009	0.003 **
	Access to Open Space	2.537	0.002 **
Environmental	Slope	1.176	0.014 *
	River Density	0.934	0.092
	Urban Green Area	—	—
Control	Return Speed of Water Level	1.053	0.010 **

Note: All data were standardized using "Z-score" conversion before regression; for the whole model, significance = 0.001, pseudo R^2 (Nagelkerke) = 0.614; Significance of the test of parallel = 0.804 > 0.005, which means the ordinal model is acceptable; * Significant at 0.05; ** Significant at 0.01.

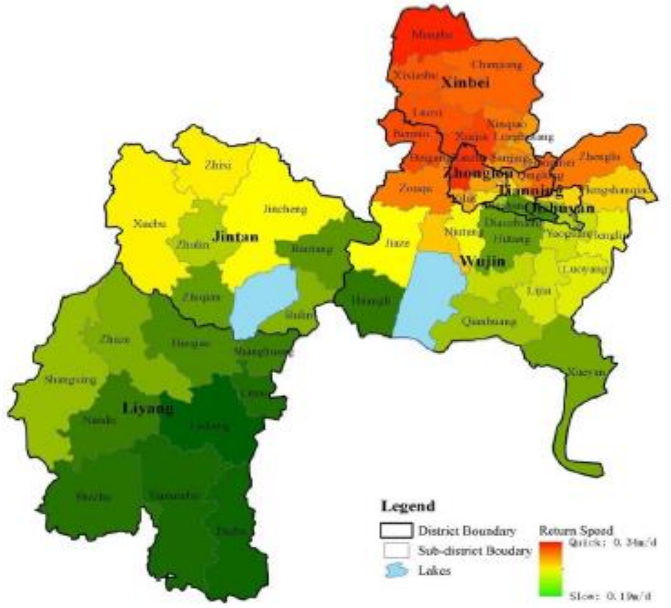


Figure 9. Average Return Speed of Water Level at Sub-district (or town) Level.

4 | Conclusion

Improvements & Limitations

I Conclusion

IMPROVEMENTs

- Propose a new method to measure recovery capability, using change detection analysis based on the time series of waste-water and waster gas discharge/emission data;
- Build a linkage between recovery and disaster resilience, using recovery measurement as external validation to identify metrics of resilience;
- Make it possible for government and urban planners to detect dominant factors in building up community resilience based on the results of logistic regression analysis.

LIMITATIONs

- Consider kinds of data sources for a more comprehensive recovery measurement given the arrival of the “Age of Big Data” (i.e. radar data, traffic flow data, social media, etc.);
- Collect more potential resilience indicators if possible;
- Incorporate developed change detection models


THANKS

Recent Publication:

Song, J., Huang, B., & Li, R. (2017). Measuring recovery to build up metrics of flood resilience based on pollutant discharge data: A case study in East China. Water, 9(8), 619.

Song, J., Huang, B. & Li, R. (2018). Assessing local resilience to typhoon disasters: A case study in Nansha, Guangzhou. PLoS ONE 13(3): e0190701. https://doi.org/10.1371/journal.pone.0190701.

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Received: 14 June 2017; Accepted: 15 August 2017; Published: 18 August 2017

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RESEARCH ARTICLE

Assessing local resilience to typhoon disasters: A case study in Nansha, Guangzhou

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