Brief communication:

Composite Urban Resilience to Typhoon Disasters: An Assessment of 27 Cities in Seven Major River Basin, China

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Abstract. Accompanying climate change, typhoon disasters have been occurring globally with high frequency and
10 intensity, causing huge property damages and losses of life. To strengthen disaster resilience is a vital policy target in
contemporary China, but few studies compare urban resilience to typhoon in different watersheds. To fill this gap,
we construct a composite model by an indicator-based system, and adopt the Fussy-entropy TOPSIS method to assess
urban resilience in China's seven major river basins. The results show that the *Haihe* Basin and the provincial capitals
had a higher resilience score than others, while cities of the *Pearl* River Basin are relatively weaker. In some regions
15 with weak economic level, however, the evaluation score value of resilience was partially higher partly attributing to
the support of government investment, local infrastructure, water conservancy projects, and the city planning. This
research may benefit river basin of different conditions to enhance urban disaster resilience, and provides a realistic
reference in response to typhoon threats.
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20 **1 Introduction**

Typhoon is one of the frequent natural hazards, which caused widespread damage particularly in coastal
areas and become a growing threat as global climate change evolves. The World Meteorological Organization
(WMO) considers a typhoon a tropical cyclone with central sustained winds of force rating 12 to 13. China has
long suffered from floods and rainstorm caused by typhoon, resulting in significant losses and casualties.
25 According to National Climate Bulletin in 2023, China incurred 345.45 billion yuan of direct economic losses from
various types of disasters, of which typhoons caused a total of 47.49 billion. Thus, the China administration had
promoted a series of actions to enhance typhoon disaster mitigation at different scales. The strategy of resilience
has also been written into China's long-term 14th Five-year Development Plan and the *2035 Vision Goal Outline*.
Generally, there are seven major river basins in China's coastal regions frequently affected by typhoon including
30 the *Yangtze, Yellow, Pearl, Huai, Hai, Liao,* and *Songhua* Rivers. Compared with other regions, these basins faced a
higher risk and demanded more prepareness to enhance disaster resilience.

Resilience, a multi-disciplinary composite concept, has sparked heated discussion in the realm of disaster and
urban planning, and scholars designed assessment framework from diverse perspectives(Song, 2018; Wang, 2020;
Yang, 2022) by introducing multiple methods (He, 2018; Kim et al., 2019; Peng, et al. 2023). Overall, multi-scale

35 experimental techniques are highly favored. However, there remain gaps in constructing composite indicators as well as regional analyses to reflect urban resilience in responding typhoon disaster. Compared with other types of disasters, typhoon brought severe floods and derivative destruction, which could severely harm city's short-term economic growth, local ecological environment and critical infrastructure such as the hydraulic facilities.

In light of this, this brief communication aims at bring up the subject of urban resilience assessment for
40 typhoon disaster by highlighting indicator-based framework of economic, social, environmental and institutional elements. By the Fuzzy-entropy TOPSIS method, we assessed disaster resilience of 27 key cities in seven major river basins in China, which addresses the heterogeneity of those typhoon-prone regions and the accessibility of data. A greater consciousness on the relevance of urban resilience measurement is essential to foster additional investigation and attention in the academia.

45 ## 2 Analytic framework and method

2.1 Indicators

Fostering resilience in handling environmental, socioeconomic risks has captured the attention of academics across disciplines, sectors, and scales. As contemporary cities continue to grapple with more challenging internal or external shocks, urban resilience has become an increasingly favored concept. Despite of disputed viewpoints
50 (Meerow,2016), urban resilience is commonly deemed as a vital capability in responding disasters, and scholars have built the disaster resilience index by constructing a multi-indicator framework in different scenarios (Marzi, 2019; Song, 2020), which also inspires the measurement of regional resilience for typhoon disaster. For instance, Siebeneck (2015) assessed the typhoon-induced flood resilience in Thailand by 25 variables. Moghadas (2019) assessed the resilience in cities of Tehran by scoring indicators. By reference to the composite resilience, scholars
55 around the globe investigated city resilience to disasters under multiple dimensions covering the economical, social, institutional, and environmental aspects (Labarda et al., 2017; Dasgupta et al., 2020; Nie et al., 2021).

Based on studies in disaster resilience index (Song, 2018; Scherzer, 2019; Rezvani et al.,2024), we construct the assessment framework from four dimensions, and select 19 indicators to measure urban resilience to typhoon disaster (see Table1). Considering the potential cascading effects of typhoons, often theorized as interconnected
60 systems, the composite indicators are integrated by adopting a multi - dimensional approach. For instance, we incorporate the critical infrastructure impact with such indicator as annual surface runoff, capacity of large reservoirs and power grids to reflect the linked influence of floods caused by typhoon. Specifically, the economic dimension measures the overall economic capacity in a city (Cutter et al., 2016; Hechanova, et al., 2018), which encompasses the financial support capacity, individual economic support capacity, and health care capacity after
65 suffering a typhoon disaster. The social dimension describes the demographic and medical level in response and post-disaster reconstruction. Generally, densely populated cities are vulnerable to typhoon due to intensive human activities, while on the contrary, areas with lower population density are less victimized in the face of typhoon. Also, the number of hospital and health center beds per 1,000 people is an indicator that can reflect urban infrastructure capacity in medical rescues. The environmental dimension both includes natural and man-
70 made condition, within the former includes the impact of precipitation by typhoon, and the latter incorporates human construction, such as the green space coverage rate in built-up areas, the quality of water conservancy projects, and storage of reservoirs. The managerial dimension herein is to measure the capacity of configuration in facilities and cross-departmental collaboration, for instance, the level of lifeline infrastructure, the joint collaboration of typhoon response, and the level of city's hydraulic sector information service.

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Table 1. composite indicators of urban resilience for typhoon disaster

Dimension	Factor	Indicator	Direction
economic	economic development level	real GDP per capita (*yuan*)	positive
	financial support capability	fiscal expenditure per capita (*yuan*)	positive
	individual financial capability	disposable income of residents per capita (*yuan*)	positive
	medical security capability	proportion of urban healthcare fiscal expenditure (%)	positive
social	demographic factors	city density of population (*person/km²*)	negative
		the proportion of urban permanent population to the total household registered population (%)	negative
	medical & public health conditions	number of beds in city hospitals & clinics (*unit*)	positive
		number of health centers per thousand people (*unit*)	
environmental (urban critical infrastructure)	climate conditions	annual city precipitation (*mm*)	negative
		annual average temperature (℃)	negative
		annual surface runoff (*100 million cu.m*)	positive
	land conditions	urban crop sowing area (*thousand hectares*)	positive
		density of green space in city built-up areas (%)	positive
	city water conservancy facilities	construction of water conservancy projects (*level*)	positive
	lifeline engineering construction	city density of drainage pipelines (*km/sq.km*)	positive
		paved roads per capita (*sq.m*)	positive
Managerial (administration)	disaster response collaboration	number of cross - departmental emergency response plan among cities (*unit*)	positive
	hydraulic engineering team	number of water resources management professionals per ten thousand population (*unit*)	positive
	level of information disclosure	number of online typhoon information published by city governments' meteorological bureau (*pcs*)	positive
	joint monitoring for disasters	number of policies jointly issued or published by city governmental departments (*unit*)	positive

2.2 Method

As stipulated above, the indicator-based framework has mirrored the dynamics of urban resilience and bore
80 significant relevance to the characteristics of typhoon response. Based on this, the Fussy-entropy TOPSIS method
was adopted herein to assess urban resilience of sample cities. This method exhibits flexibility in accommodating
various data distribution states and sample sizes, boasting a relatively accurate calculation in disaster resilience
assessment (Hajek, et al., 2019;Zhang et al., 2021; Mer, 2021). Its core application lies the objective of identifying
optimal solution and the counterpoint of negative optimal solution for each evaluated object across the weighted
85 standardized judgment matrix. The process of the Fussy-entropy TOPSIS can be obtained as referenced by Mer
(2021), which is omitted hereinafter due to layout constraints.

2.3 Data collection

The indicator data were acquired from the statistical yearbooks published by city governments, China's
population census, the regional hydraulic bulletins, the annual reports posted on the website of meteorological
90 department, and urban archive documents. A sample of total 27 cities in seven major river basins in China was
selected for this study. Although typhoon is categorized in magnitudes, such as tropical depression, storm, severe
typhoon and super typhoon, there were no data for each category across the sample cities. For this reason, we did
not classify typhoon into subcategories by magnitude in this research, and select officially disclosed information
by the principle of data accessibility.

3 Results and discussion

3.1 Spatial variation in urban resilience

By the calculation score of urban resilience (Figure 1), cities within the seven river basin could be categorized into four levels in its capability. The smaller the level is, the stronger is the urban resilience to typhoon. In specific, cities at Level 1 to Level 3 are respectively Shanghai (average score 0.5907), Yantai (average score 0.4087), Haikou and Beijing. Level 4, rating from 0.2 to 0.3, include city of Xuzhou, Zhanjiang, Tianjin, Shenyang, Guangzhou, Harbin, Taizhou, Changchun, Hangzhou, Changsha, and Bengbu. Level 5, rating from 0.1 to 0.2, include city of Nanjing, Wuhan, Jinan, Fuzhou, Zhengzhou, Wenzhou, Yulin, Wuhu, Hefei, Nanning, and Dandong. Level 6 is labeled to Kaifeng with a composite score less than 0.1.
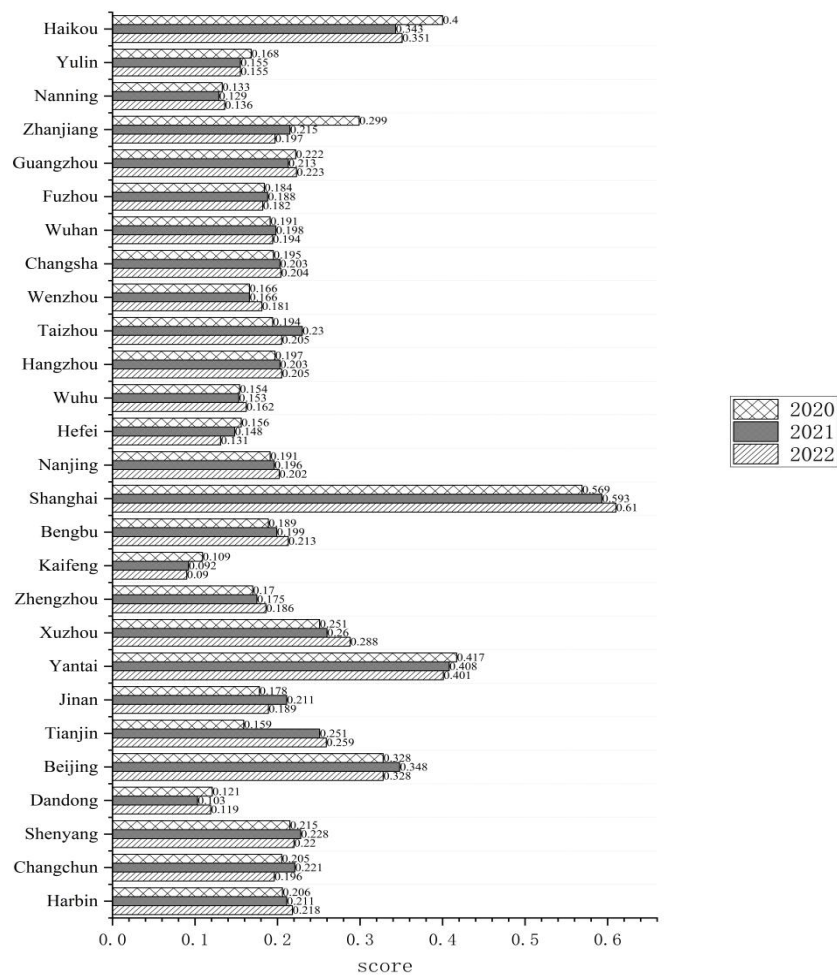
Fig. 1. Composite calculation score of urban resilience for 27 sample cities
Notes: The score denotes the resilience index by rating (0-1) in the specific year. The higher the score is, the stronger urban resilient is in responding typhoon disaster

Generally, the occurrence and disastrous impacts of typhoons are affected by geographical and meterological factors. Therefore, it needs to examine the practical discrepancies in similar geographical environment. Due to the different watersheds of each city, we divided the 27 cities into seven river basin regions, and listed scores for each city under the assessing dimension.

Comparatively, the resilience scores to typhoon in northeast region (*Songhua* & *Liao* River Basin) was slightly stronger than southeast region (*Pearl* River Basin). Although cities in southeast region showed a rapid economic growth compared with that of the northeast region, the southeast region had a lower investment in the reservoir construction, which was one of the major economic indicators in our resilience assessment system(weight >10%), and the storage capacity of large and medium-sized reservoirs in the Northeast *Songhua* and *Liao* River Basins is significantly higher than that of other basins.Overall, the *Pearl* River Basin has a tropical and subtropical climate with an average annual temperature exceeding 22°C and precipitation exceeding 1,500 mm (Sheng, 2015), making them highly vulnerable to typhoons. As for the social dimension of resilience assessment, the river basin of southeast region with a higher population density acquired stronger medical and rescue capability in typhoon response, while the Northeast river basin does not possess adequate water facilities. In terms of environmental dimension, the northeast river basin had less precipitation annually and a lower risk exposure to typhoon than the southeast coastal areas. Moreover, the resilience score of the *Yellow-Huai* River Basin and *Yangtze* River Basin (including major cities in China's provinces of Shandong, Henan, Jiangsu, Zhejiang and Anhui) is stronger than that of the Northeast region. Both river basins perform better by its resilience score in terms of social and managerial dimension, which can be attributed to the high influx of R&D investment and the enhancement of technical innovation. The *Yellow-Huai* River Basin, located in the eastern regions of China with better climate conditions and a high level of urbanization, attracts a large inflow of economic resources and creates a better pool of specialized human resources in water conservancy and economic protection.

3.2 Intra-watershed comparison

China's administrative system endows a superior status either in economic and political aspects for provincial capitals, and these cities usually exhibit higher levels of capability to disasters than other prefecture-level ones. By the research result likewise, the provincial capital cities (e.g. Harbin, Nanjing, and Guangzhou) have higher resilience scores than other types of cities in the provincial region. In other words, these cities demonstrate more capability of resilience compared to prefecture-level cities in confronting typhoon disasters. However, there are also exceptions in some watersheds. For instance, Jinan, the capital city of Shandong Province, is slightly lower in resilience score than Yantai, a prefecture-level city in Jiaodong Peninsula, which can be attributed to two reasons. First, Yantai, a coastal industrial city, is economically prosperous because of industrial power and infrastructures, which provide substantial disaster response resources and practical experiences. For its strong economic strength and the coast-border geographical location adjacent to the Yellow Sea and Bohai Sea, the local administration was more attentive to investments in tackling typhoon. Statistics show that the proportion of expenditure spent on typhoon response in Yantai throughout the year was 3–4 times than the capital city of Jinan. Second, the population density of Yantai was relatively low compared with Jinan, which benefits the city when calculating *per capita* indicators in urban resilience assessment. It is particularly worth mentioning that, Xuzhou City, as the the second tiers city in Jiangsu Province, exceeds many provincial capitals in resilience scores, and its composite scores show an increasing tendency annually. The wide spread of drainage network around the city and rapid construction of lifeline project since 2020 has enhanced its performance in precipitation caused by typhoon, which promotes its overall environmental resilience for typhoon.
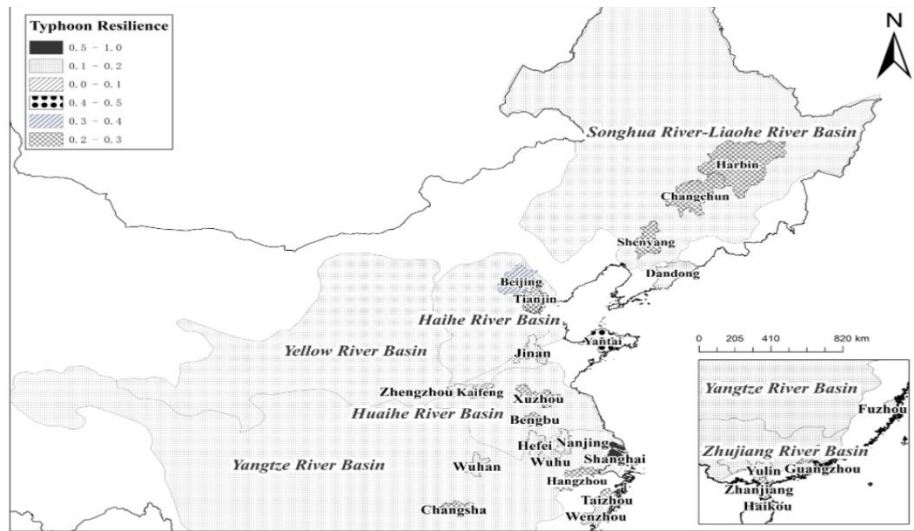
Fig. 2. Resilience rating of 27 typhoon-affected cities in respect to watersheds

In the *Songhua* River Basin and *Liaohe* River Basin, cities perform poorly for the resilience value in economic and managerial dimension but relatively better in the social and environmental aspect. Compared to Shenyang, the capital city of Liaoning Province, Dandong has a weaker industrial base and a long coastline in Northeast China, but hold a spark advantage in water conservancy condition. In the Songhua River basin, Harbin ranks 10th out of 27 cities in the overall resilience score, while Changchun ranks 12th. This difference may be closely related to the high population density in Changchun, and weaker reservoir storage capacity compared to capital city of Harbin. For the whole northeast region in China, Harbin has the largest reservoir capacity (12,966 million cubic meters). In the reality, reservoirs play a vital role in dissipating heavy precipitation caused by typhoon in a short period of time and staggering the peaks of rain. Moreover, the Haihe River Basin differs considerably in the resilience score, particularly among Beijing and other cities. During 2020-2022, Tianjin is significantly lower (0.2230) than Beijing (0.3347). Obviously, Beijing overwhelms others in the urban resilience of economic, social and administrative dimension, with its water conservancy sector ranking first in terms of information disclosure、 risk early warning and the disaster response.

In the *Yellow-Huai* River Basin, the observed city with the highest level of resilience score is Jinan, which may be related to its administrative location as the capital city of Shandong province and the command center of the Liberation Army in China's Northern Theater of Operations. By the assessment result, Jinan city scores high on the resilience dimension of social and administrative aspect. Besides, Jinan has an advantage of professional talents and personnel in typhoon disaster rescues, including 27 water and disaster response practitioners per 10,000 population in 2022, far more than any other city in the river basin. By comparison, as a capital city in Henan province, Zhengzhou scored lower on the resilience calculation. The scale of inter-provincial population outflow in Henan Province is among the highest in China, resulting in a lower level of technical expertise for disaster reduction, which is one of the barriers to enhancing resilience to typhoon.

In the developed regions of *Yangtze* River Basin, Hangzhou has the highest level of overall resilience score, mainly due to its top ranking in the reservoir capacity and environmental management practitioners. The leading development position in the *Yangtze* River Delta gives the cities of Shanghai, Hangzhou, and Nanjing a very high economic advantage, attracting high-level talents from all over the country, and provide abundant talents

180 including disaster relief and emergency aids. Among the *Yangtze* River Basin, Taizhou has the lowest level in resilience score, which may be related to the city's low reservoir capacity and lack of critical facilities to mitigate heavy rainfall caused by typhoon.

Cities in the *Pearl* River Basin are categorized into two levels, Guangzhou and ZhanJiang in Guangdong province rating the fourth and Nanning in Guangxi province rating the fifth position. The *Pearl* River Basin has
185 abundant annual rainfall, accounting for about 13% of the national runoff. The Xijiang and Beijiang rivers meet as the main source of typhoon-induced flooding in the delta. Nanning and Yulin, although less pressurized in terms of population density and large reservoirs of capacity, the level of water conservancy construction and disaster relief facilities is low, leading a weaker ability to confront typhoon. From an economic perspective, Nanning and Yulin lag behind other provincial capital cities in terms of governmental fund support. Particularly, although
190 Nanning encountered a frequent typhoon landfall, it had a small number of reservoirs for precipitation due to lack of long-term financial input, which may result in weak response capacity to sudden typhoon rain.

4. Conclusion

The brief communication reports a multi-dimensional assessment framework focusing on urban resilience to
195 typhoon disaster and applies 27 cities in China's seven major river basins during 2020–2022. Several composite indicators under the economic, social, environmental, and managerial dimension were selected and the Fussy-entropy TOPSIS method was applied. We found that the urban resilience in these watersheds could be ranked from high to low: *the Haihe River Basin, the Liaohe River Basin, the Yangtze River Basin, the Songhua River Basin, the Yellow-Huaihe River Basin, the Nandu River Basin and the Zhujiang River Basin.* In specific, we obtain the following
200 findings based on the resilience assessment of these basins to typhoon disaster.

(1) The economic development level is not synchronized with resilience to typhoon in some basins. Our findings show that the resilience score in northeast China was higher than that in the southeast, which did not match the economic status of two regions. Overall, the investment direction of regional economic resources, especially government fiscal investment, and the condition of disaster prevention infrastructure are more crucial
205 to cities' capability of tackling typhoon, rather than simply the economic growth. We found that some cities in the watershed with a higher percentage of financial expenditure on underground tunnel facilities demonstrated a stronger capacity for divert floodwaters and disaster response when typhoon occurs.

(2) In the assessment of environmental dimension, climatic condition, land resource, and infrastructure are critical factors in affecting urban resilience to typhoon. Our research showed that cities in the coastal region with
210 more risks of typhoon-induced rainwaterlogging scored higher, mainly thanks to its infrastructure of extensive water conservancy projects, such as large and medium-sized reservoirs, hydropower station, waterway and harbor projects. A typical case was the Fuzhou City in Fujian. Although it received more annual precipitation caused by typhoon, the large-capacity reservoirs and widely distributed air-raid shelter infrastructures reduced destructive shocks in the past decade.
215 (3) The managerial dimension with respect to urban resilience herein refers to the response capacity by local administration, particularly when tackling potential cascading effects of typhoon. In this study, the status of cross-departmental collaboration was an important indicator. Through fostering dynamic linkage of departments, it is conductive to form an efficient resource scheduling platform, promote a closed-loop response, and further enhance the systemic resilience in responding to compound risks of typhoon disaster. Moreover, the government
220 ought to enhance the level of early warning as well as information disclosure of typhoon through the technical approaches, for instance, strengthening the integration chain of "monitoring-forecasting-dissemination" by the support of such technology as satellites navigation, supercomputer, artificial intelligence.

To sum up, we tried to provide a holistic view of urban resilience assessment to typhoon by constructing a composite framework, but there are still gaps that need to be filled. Urban resilience to typhoon is inherently dynamic, evolving with changes in economic, environmental, social, and infrastructure conditions, thus more heterogeneous cognitive factors need to be added. Future research could probe the conceptualization of potential cascading impacts of typhoon by novel methodologies with a dynamic perspective upon resilience assessment.

Data availability

The data is available on reasonable request.

Author contribution

Liu: conceptualization, analysis, writing – original draft, editing and funding acquisition.
Yang: data curation, writing – original draft, **Wu**: visualization, writing – review

Declaration of competing interest

The authors declare that neither of the authors has any competing interests.

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