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Research Article

Responses of Urban Ecosystem Vulnerability and Restoration Assessment on Typhoon Disaster: A Case Study of Zhuhai City, China

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With the frequent occurrence of extreme disasters and the development of urbanization, the ecological vulnerability of urban system has been seriously affected, which has become an important issue in urgent need of research. In this study, a comprehensive analysis method of exposure, sensitivity, responsiveness, and resilience was used to establish an ecological vulnerability assessment model based on the impact of typhoon. With the help of big data analysis and model, this paper explored the impact and response of typhoon Hato on Zhuhai's ecological vulnerability and restoration. Our results showed that under the influence of Hato, Jinwan district showed higher vulnerability, followed by Doumen district and Xiangzhou district. The lowest vulnerability of Xiangzhou district mainly for its coping capacity was significantly higher than the other two districts. Judging from the recovery situation shown by big data, Doumen and Xiangzhou districts recovered relatively quickly in terms of hydraulic and communication systems. The results of this study can provide a theoretical reference for vulnerability assessment, predisaster prevention, and postdisaster recovery of typhoon disaster risk areas.

1. Introduction

Typhoon, as a common natural disaster, has great destructive effect on human society with considerable economic losses, which exceeds other natural disasters such as earthquakes [1]. The average annual direct economic loss from tropical cyclone disasters in the world in the past ten years is about 55 billion U.S. dollars [2]. China is one of the countries that severely affected by typhoon [3, 4]. Because of the severe losses caused by typhoons, it is necessary to evaluate disasters and carry out disaster management. Therefore, research of tropical cyclone disaster risk assessment and management have received more and more attention from the scientific community [5, 6].

Disaster risk assessment is a quantitative analysis and assessment of the possibility and possible consequences of disasters with different intensities. The assessment is an important bridge to closely link the hazard factors and the vulnerability of the disaster-bearing body. As early as the end of the nineteenth century, the improvement of disaster observation technology and the development of risk mapping technology prompted the emergence of catastrophe models for the simulation and evaluation [7, 8]. Much attention has been paid on the assessment of storm surge disaster losses caused by typhoons, and the disaster losses have been quantitatively assessed by establishing a loss assessment model [9–13]. Loss assessment of typhoon is one of the hotspots and difficulties in disaster theory research. However, the lack of scientific norms for the investigation and assessment of natural disaster losses, coupled with the unpredictability of natural disasters, further increase the difficulty of data collection and assessment. With the "vulnerability of hazard-bearing bodies" put forward in the 1980s, the concept of vulnerability has gradually been widely used in many domains like nature, society, economy, and environment [14].

There are two main research methods for vulnerability assessment of disaster bearing body, including index system method and quantitative vulnerability curve. The index system method is a semiquantitative calculation method, which mainly expresses the relative vulnerability of the evaluation unit by establishing the evaluation index system and calculating the vulnerability index of the disaster bearing body. At present, index system method has been widely used in the vulnerability assessment of a single disaster-bearing body [15], multiple disaster-bearing bodies [16], and disaster-bearing systems [17], but different studies have different understandings of the causes of disasters and the performance characteristics of disaster-bearing bodies, and the established index systems are different. In addition, the research on the vulnerability of disaster-bearing bodies is highly regional. Therefore, the process of using the index system method to assess the vulnerability of hazard-bearing bodies is artificially subjective. Moreover, the vulnerability curve is a quantitative vulnerability assessment method based on the relationship between the strength parameters of different hazards and the loss rate of the disaster-bearing body [18]. At present, most research focus on the construction of vulnerability curves between typhoon wind speed, submergence depth, earthquake intensity and other hazard factors, and the loss rate of disaster-bearing bodies, such as houses and crops [19]. This method does not involve the assessment of social, economic, and environmental vulnerability levels and emergency response capabilities to disasters. It only represents the vulnerability measurement of absolute physical parameters.

This paper will use the index system method to evaluate the impact of typhoon Hato on urban ecological vulnerability. And using big data makes the analysis method in this paper have strong universal adaptability. Recently, there are many applications for typhoon disaster risk assessments [20, 21]. However, most of the disaster mitigation work relies on the short-term forecast results of the meteorological department's typhoon model for the input of hazard factors (e.g., wind and rain), while the quantitative research on typhoon disaster vulnerability of specific disaster-bearing bodies remains blank. In terms of typhoon assessment methods, the current typhoon pre-assessment focuses on obtaining high-accuracy data [22], but the postdisaster vulnerability assessment still often lacks time-sensitive data with redundant computation process [23]. Therefore, it is concluded that the effective and accurate postdisaster vulnerability assessment is particularly necessary for disaster assessment. Moreover, research and practice have proved that the unique advantages of big data in feasibility, timeliness, and accuracy make it successfully applied in various fields [24, 25].

As such, based on the secondary data derived from the "octopus" network information resource picking software and data collected by traditional surveys, this paper establishes a social economic and ecological system to evaluate the impact of typhoons on urban ecological vulnerability. Zhuhai, a city often hit by the south subtropical monsoon, was selected as the study region. This study is to develop a conceptual model of aspects of exposure, sensitivity, resilience, and response to typhoon Hato; to explore how big data can provide input data to undertake a socioeconomic assessment of vulnerability, using "Octopus" software; to produce a socioecological vulnerability assessment tool; and to evaluate the methods and outputs from the socioecological vulnerability assessment tool. We consider that this study provides a theoretical reference for disaster prevention and reduction and the establishment of sustainable, resilient cities.

2. Data and Methodology

2.1. Study Site. Zhuhai (see Figure 1) is located between $21°48'$-$22°27'$ north latitude and $113°03'$-$114°19'$ east longitude. By 2020, Zhuhai City has a total land area of $1736.45\,km^2$ with three administrative districts, namely, Xiangzhou district, Doumen district, and Jinwan district, including 15 towns and 9 streets. Zhuhai City occupies the largest ocean area, the most islands, and the longest coastline in the Pearl River Delta. According to the seventh national census, the population of Zhuhai City is 2.44 million at the end of 2020 [26]. Typhoons usually occur from June to October, with an average of about four per year. Such disasters severely affecting Zhuhai City average about one a year, and there are about five periods of torrential rains [27]. Zhuhai land use data were derived from "Zhuhai Land Use Master Plan."

Hato was one of the strongest storms in the global range in 2017 [27], which landed at the coast of Jinwan district, Zhuhai City, at about 12:50 on August 23, 2017, causing considerable losses to Zhuhai, Hong Kong, Macau, and other regions [28–31]. In addition, the maximum wind force near the center of Hato is force 14 ($45\,m{\cdot}s^{-1}$), and the minimum pressure in the center is 950 HPa [30]. Monitoring showed that the Zhuhai National Weather Station observed an instantaneous gale of $51.9\,m{\cdot}s^{-1}$ (level 16) between 12:10 and 12:15. Moreover, Hato brought violent showers to Zhuhai City, causing two deaths and the collapse of 275 houses [27]. Some roads were blocked due to falling trees. The total direct economic loss was around 0.8 billion USD [27].

2.2. Data Collection. This study uses the big data analysis method to obtain the relevant data of indicators such as power, traffic, and telecommunications signal recovery speed. However, due to gap between the publication time and the occurrence of Hato, it is hard to quickly obtain the information of all affected points. Big data comes from Weibo software, a common social platform in China (like the twitter); such platform documents people's dynamics, thoughts, and locations. This study used the network information resource picking software, a program to automatically grab Internet information resources to understand the locations affected by the typhoon; the specific process is shown in Figure 2.

The relevant keyword selection parameters were shown in Table 1. The location information was derived from the location data of Weibo users. The duplicate data caused by forwarding or other reasons was deleted after manual review. Because typhoon Pakhar landed on August 27, 2017, and affected the west bank of the Pearl River and western Guangdong Province, the data on August 28, 2017, and

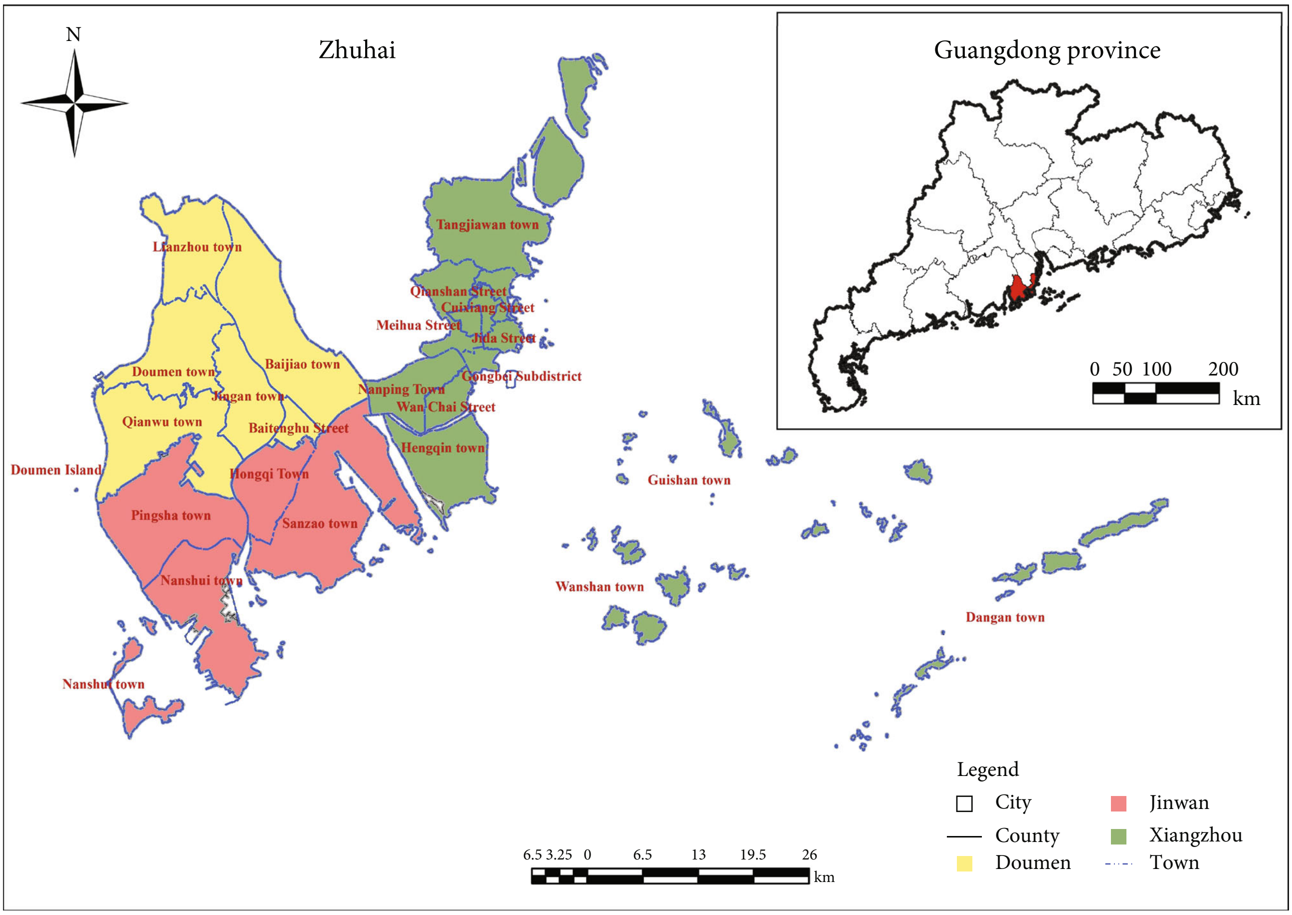


Figure 1: Zhuhai City administrative map.

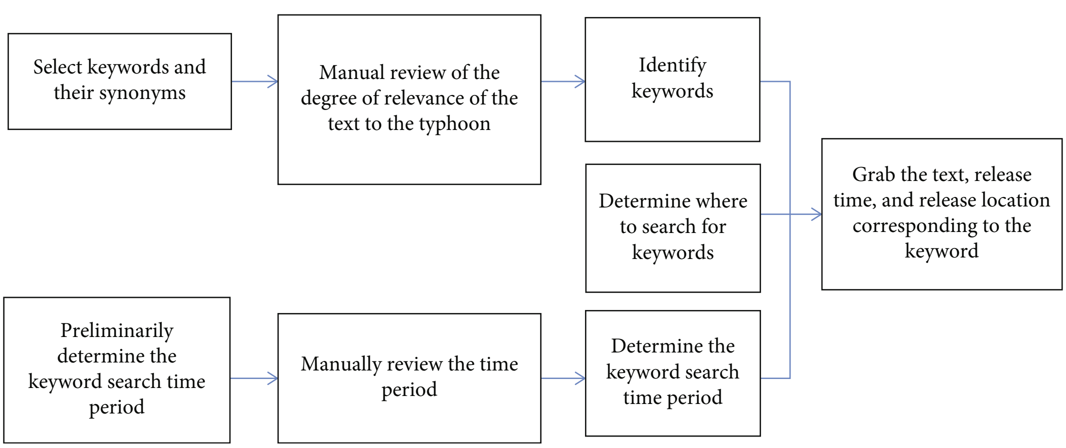


Figure 2: Keyword selection flowchart for typhoon disaster information.

later were deleted in the analysis. In the end, it was determined to adopt the release volume of all keywords from August 23 to August 27, 2017. Then, data on recovery speed data of power, traffic, and telecommunication signals were obtained.

In order to obtain the data of exposure, response, and sensitivity of Zhuhai City, this paper adopted the data in the 2018 statistical yearbook published by this city. The data included district area, typhoon wind force, population density, proportion of primary industry, proportion of tertiary industry, ecological index, regional GDP, per capita disposable income of urban residents, general public service expenditure, and medical and health institution expenditure.

2.3. Methods

2.3.1. The Vulnerability Evaluation Index System. Vulnerability refers to the degree of self-change of the system after

Table 1: Vulnerability assessment index system of socioecological systems under the influence of typhoon disaster in Zhuhai City.

Primary indicators	Secondary indicators
Exposure	Land area
	Wind force
	Population density
Sensitivity	Proportion of primary industry
	Proportion of tertiary industry
	Ecological index
Response	Regional GDP
	Per capital disposable income of urban residents
	General public service expenditure
	Medical and health institutions expenditure
Resilience	Electricity restoration speed
	Traffic restoration speed
	Telecom signal recovery speed

being damaged by various pressures. The system is jointly determined by natural, social, economic, and environmental factors and processes [32]. For this paper, the natural and social systems in Xiangzhou district, Doumen district, and Jinwan district of Zhuhai City were selected as the disaster-bearing body on the basis of fully considering the research object and the characteristics of the typhoon disaster. This study summarized the main risk factors of climate change and the evaluation factors used by Sajjad et al. to evaluate the vulnerability of coastal cities [33]. These assessment factors were based on the principles of science, completeness, feasibility, and practicability, combined with the vulnerability caused by exposure. This study considered indicators from four aspects [34], sensitivity [35], resilience [35, 36], exposure, and response, respectively. A social-ecological system vulnerability index system was established for three districts in Zhuhai under the disaster of typhoon Hato, as shown in Table 1.

Firstly, in order to evaluate the degree of damage caused by the typhoon to different regions, we selected the land area, wind speed, and population density as indicators to evaluate the different conditions of each area exposed to the typhoon. Secondly, ground roughness characterizes the interaction between the surface and the atmosphere, reflecting the reduction of wind speed on the surface and the ground in areas with high ecological index. The roughness of a typhoon was high [37], so the ecological index and the intensity of typhoon landing were negatively correlated, i.e., the higher the vegetation coverage, the less the sensitivity. And since the Hato natured with extreme wind speeds, the primary and tertiary industries were relatively sensitive. Therefore, the proportion of the primary and tertiary industries and the vegetation coverage were selected for evaluation. Sensitivity starting from the socioeconomic conditions of different regions, two indicators representing the economic level of the region and residents, and two indicators representing the perfection of the region's infrastructure and social security were selected to evaluate the region's ability to respond to typhoon disasters. Finally, based on the trend of big data changes, the perspective of affecting the recovery of residents' lives, the three indicators of power system, water supply system, and telecommunication system were selected for resilience evaluation.

2.3.2. Vulnerability Comprehensive Evaluation Model. Fuzzy comprehensive evaluation (FCE) is a decision-making method that can make a comprehensive evaluation affected by multiple factors [38]. In this study, FCE was employed as the basis of the vulnerability assessment for the various districts of Zhuhai under the typhoon Hato; the entropy weight (EW) was used to calculate the weights for every indicator. Firstly, the original data was standardized, and the EW was used to establish the weight set of all levels of indicators. Secondly, the membership function was used to combine the standardized values and the grading standards of the vulnerability comment set to construct an evaluation matrix. The comment set is an evaluation set established based on the evaluation indicators. In the vulnerability evaluation of hazard-bearing bodies, due to the difference in the importance of the selected evaluation factors, it is necessary to determine the weight. Entropy is a measure of uncertainty; the greater the amount of information, the smaller the uncertainty, and the smaller the entropy. Therefore, the information carried by the entropy value can be used for computing the weights for each factor, combined with the degree of variation of various indicators, and the tool of information entropy is used to calculate the weight of each indicator, which provides a basis for the comprehensive evaluation of multiple indicators. The weights established in this paper based on the entropy method are shown in Table 2.

Ecological vulnerability depends on four aspects: the exposure degree of the system, the sensitivity of the system to external interference, and the adaptability and recovery ability of the system. The degree of vulnerability represents the degree of vulnerability of each primary indicator. This paper divided the degree of vulnerability into three levels and used the median method and the average method to determine the grading standard of the comment set [39], that iss, the evaluation set $V = \{V1, V2, V3\} = \{\text{Low Degree of vulnerability, moderate degree of vulnerability, high degree of vulnerability}\}$. At the end of this paper, the evaluation matrix and the weight set were synthesized by matrix calculation. The value of the corresponding evaluation level of each primary indicator could be added to represent the comprehensive evaluation result of vulnerability.

3. Results

3.1. Analysis of Big Data Mining Results. Figure 3 reflected the restoration after typhoon Hato, as indicated by the change in search volume. Among the keywords, the search time span of five keywords and their synonyms, "power outage," "water outage," "tree," "injured," and "no signal," was long, and the data decreased with the passage of time. The

Table 2: Weight set of vulnerability assessment index system of socioecological systems under the influence of typhoon disaster in Zhuhai City.

Indicator	Weight
Land area	0.0844
Wind speed	0.1394
Population density	0.0792
Proportion of primary industry	0.1022
Proportion of tertiary industry	0.0615
Ecological index	0.0864
Regional GDP	0.0943
Per capita disposable income of urban residents	0.0654
General public service expenditure	0.0598
Medical and health institutions expenditure	0.0547
Electricity restoration speed	0.0662
Traffic restoration speed	0.0532
Telecom signal recovery speed	0.0532

highest number of keywords posted on the day the typhoon landed in Zhuhai, August 23, 2017. Two days later, on August 25, the number of keywords posted dropped sharply and then showed a gentle downward trend over time. In the final data, the amount approaches zero. The search volume of "tree" and "injured" decreased rapidly on August 24, and then tended to zero on August 25 and August 26, respectively. Among the keywords related to the three vulnerability secondary indicators of "power outage", "water outage" and "outage of mobile phone signal," the search volume reached the smallest on August 27, August 26, and August 26, respectively. The release of keywords is closely related to the time of the typhoon and the disaster relief situation. Therefore, it can be explained that the recovery day of each system was the day when the search volume was the smallest in each district of Zhuhai City. According to the calculation, the recovery speed of power supply, water supply, and telecommunication signals were 0.2 day^{-1}, 0.25 day^{-1}, and 0.25 day^{-1}, respectively. This represents the rate of completion of the daily restoration of the city's power, hydraulic, and communication systems, which could be used to calculate the resilience of each district.

3.2. Analysis of Visualized Results of Urban Restoration. The release of all keywords peaked on the day of the typhoon landing and gradually decreased the next day. With the continuous development of postdisaster reconstruction, the locations of failures of power, hydraulic supply, and communication systems affected by the typhoon decreased. This chapter would explore the restoration of power, hydraulic supply, and communication systems under the influence of typhoon Hato. Figure 4 reflected the repair of the power system after Hato, as indicated by the change in search volume. On the day of Hato landing, a large number of power supply failures occurred in three districts of Zhuhai City, most of which were located within the construction land. Xiangzhou district is the city center of Zhuhai city, which has a large number of commercial land and residential areas with a high

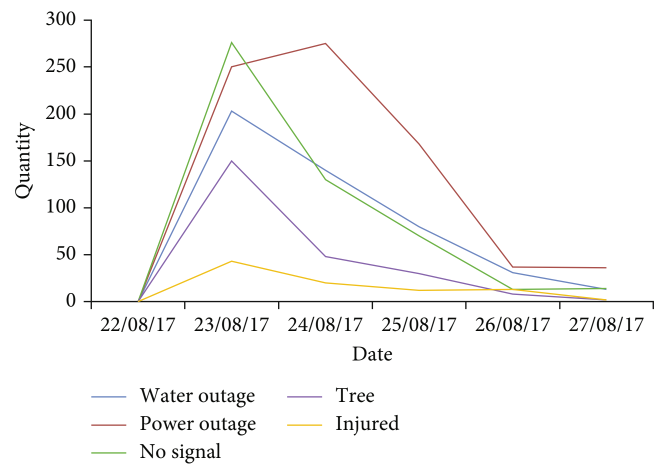
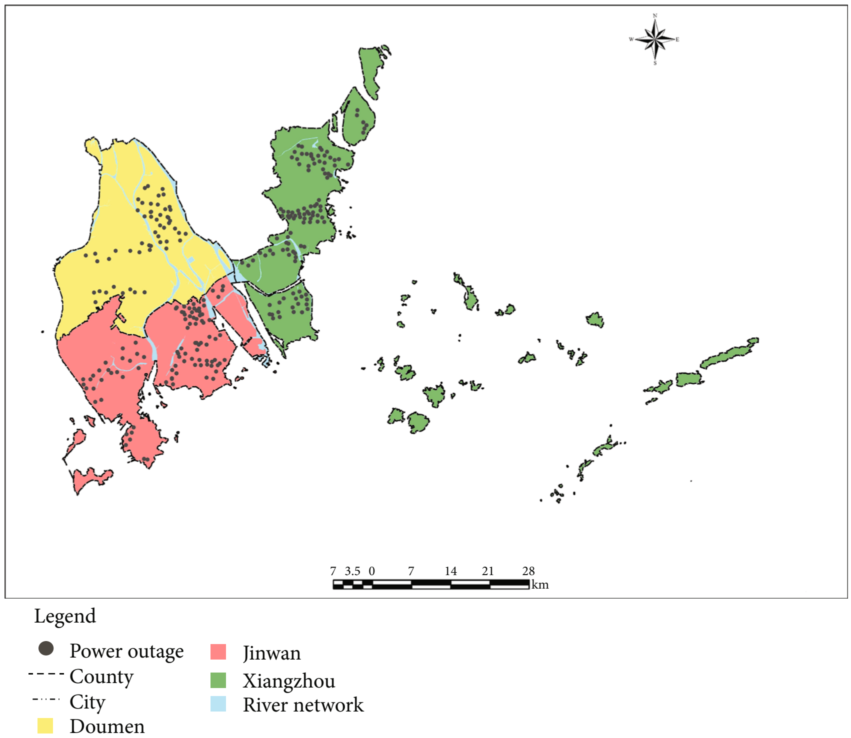


Figure 3: Search volumes of Weibo keywords before and after typhoon Hato.

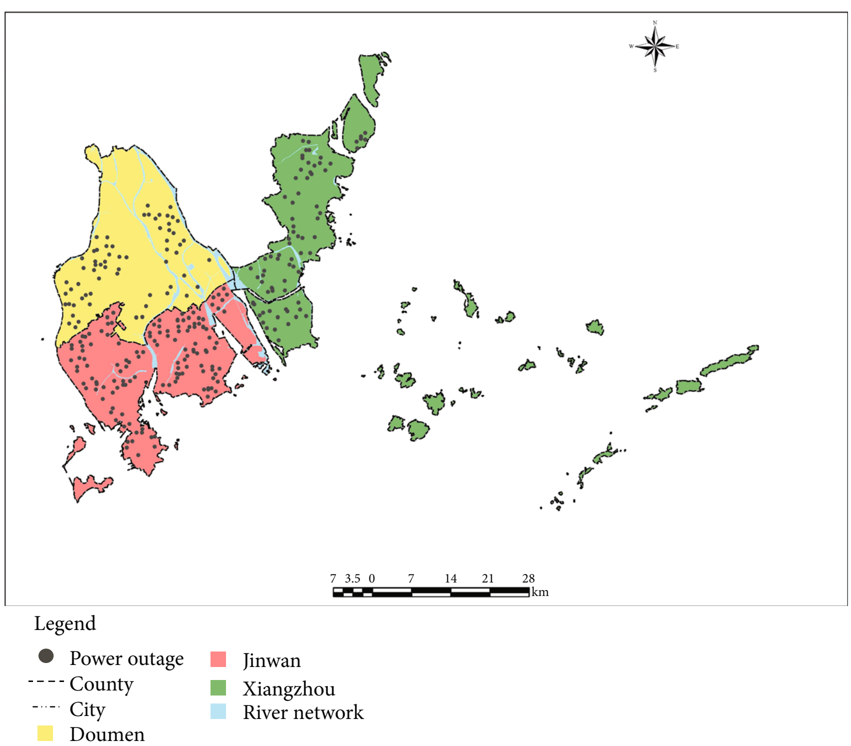
population density. Therefore, on August 23, the fault spots were concentrated in the city center, including Tangjiawan Town and Hengqin Island. By August 25, the power failure in the center of Zhuhai City was almost solved, but the power failure still existed in Tangjiawan Town and on Hengqin Island. By August 26, the power supply in Xiangzhou district was almost back to normal. The power outages in Doumen district affected mostly residential areas, such as Jingan Town and Doumen Town. As rescue and relief work continued, only sporadic areas in Doumen district were left with power supply problems on August 26. The power failure in Jinwan district was the most serious with a large number of occurrences in the whole area. As of August 27, the power supply system of coastal Sanzao Town and Nanshai Town, which were most seriously affected by the typhoon, has not been fully restored.

The repair of the hydraulic system after typhoon Hato, was shown by the change in search volume (Figure 5). On the day the typhoon landed, a large number of water supply faults occurred in the three districts of Zhuhai, most of which were located near the main roads and within the construction land. In Xiangzhou district on August 23, the breakdown points were concentrated in the city center, in Tangjiawan Town and on Hengqin Island. By August 24, the water supply had improved in the city center, but there was still a lack of water near the S32 provincial road and on Hengqin Island. By August 25, the water supply in Xiangzhou district was almost back to normal. However, water supply of Doumen district had almost cut off in residential areas and on main roads, such as Qianwu Town and the provincial road S32. With the rescue and relief work underway, only a few water supply faults remained in Doumen district near the main road by August 25. Water supply cutoff in Jinwan district was the most serious, which occurs on a large scale in the whole region. As of August 27, there were still hydraulic faults in the whole Jinwan district.

The repair of the communication system after typhoon Hato, was indicated by the change in search volume (see Figure 6). On the day of typhoon landing, a large number of communication faults occurred in three districts of

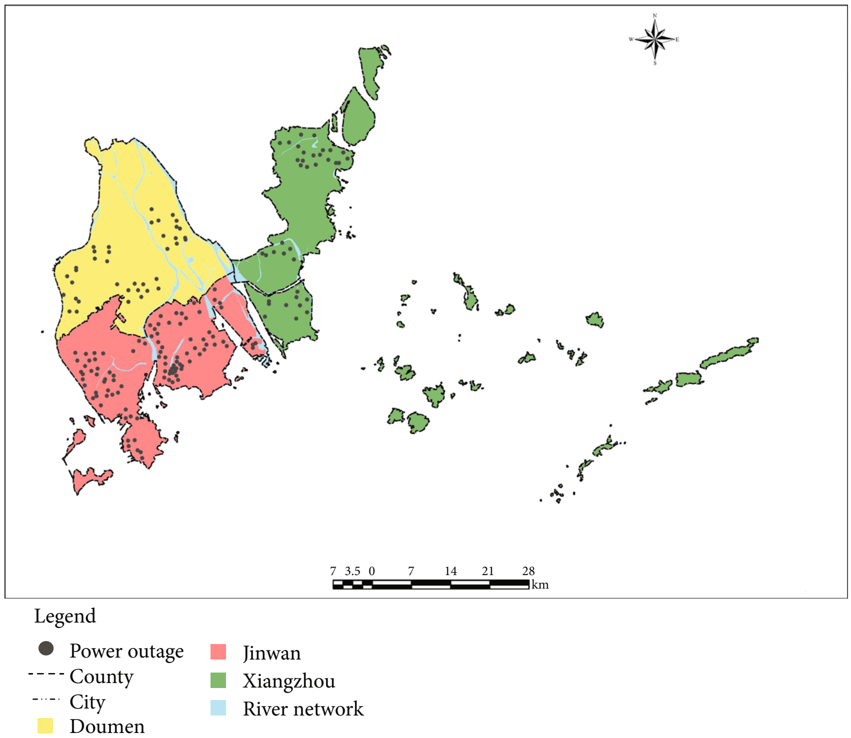


(a) August 23, 2017

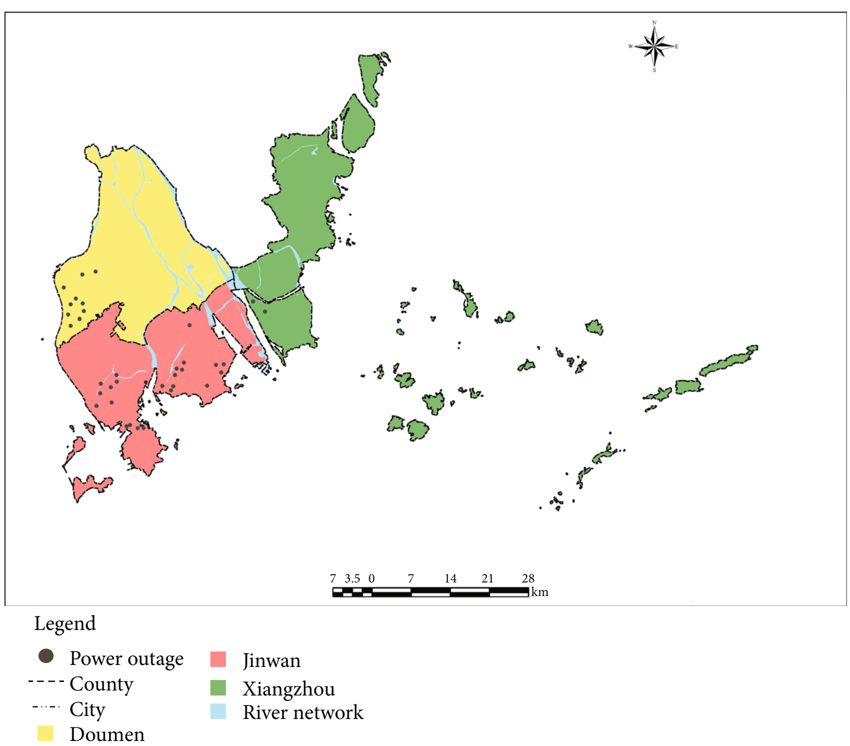


(b) August 24, 2017

Figure 4: Continued.

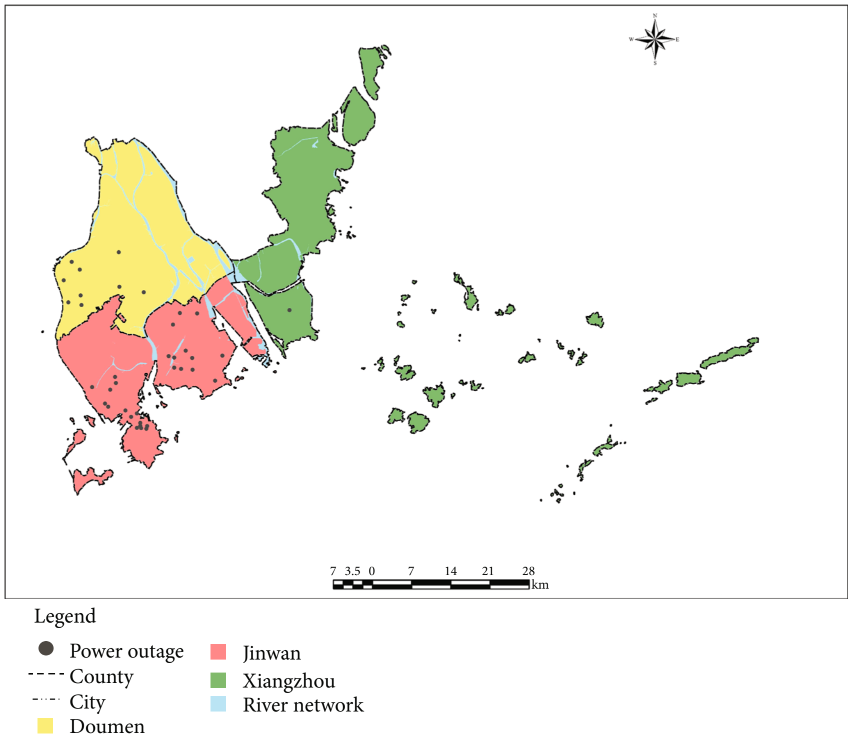


(c) August 25, 2017



(d) August 26, 2017

Figure 4: Continued.



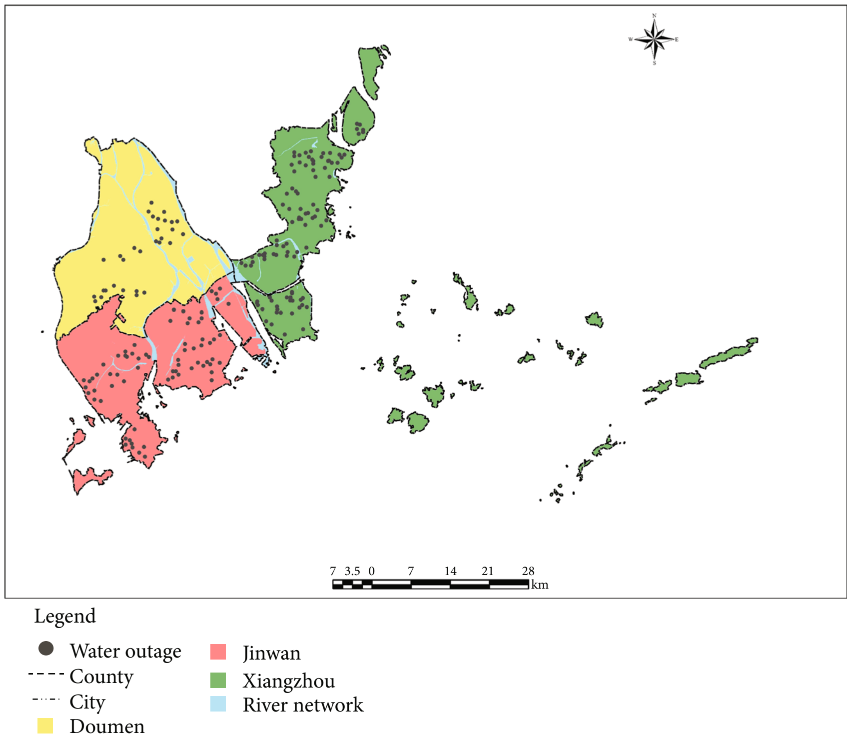
(e) August 27, 2017

Figure 4: The repair of power system after typhoon Hato.

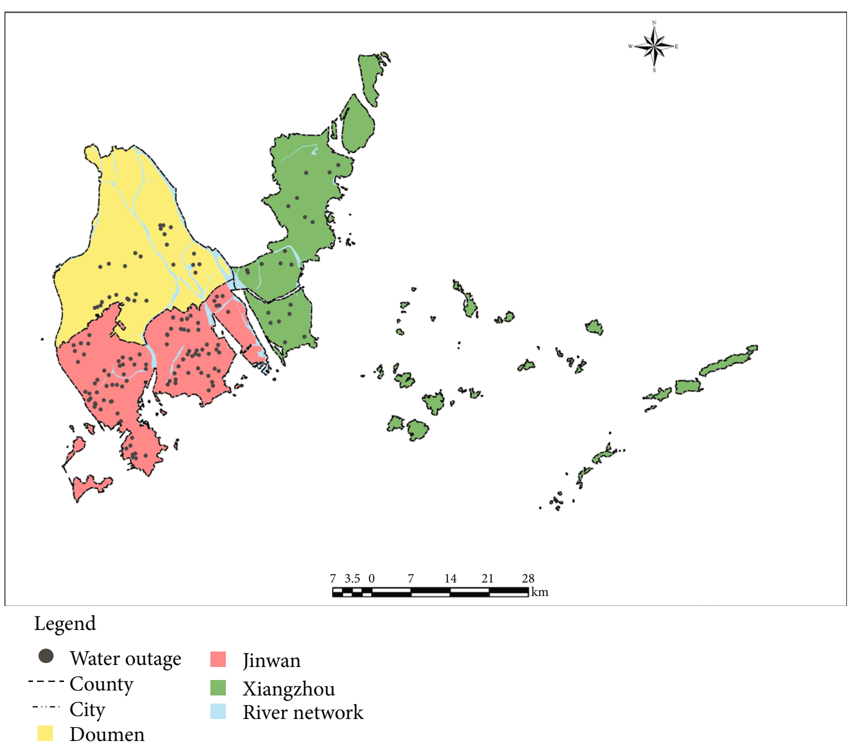
Zhuhai City, and the fault points covered almost the whole city. In Xiangzhou district on August 23, the breakdown points were concentrated in densely populated commercial service center and residential areas, such as the city center, Tangjiawan Town, and Hengqin Island. By August 24, Tangjiawan Town was almost back to normal, but there were still a few communication problems in the city center and on Hengqin Island. By August 25, the communication system in Xiangzhou district was almost back to normal. The areas without signal in Doumen district were mostly residential areas, such as Qianwu Town, Doumen Town, and Jingan Town. As rescue and relief work began, only a few communication failures remained in the vicinity of Jingan Town on August 25. The communication failure was the most serious in Jinwan district, where it occurred in large numbers throughout the whole area. By August 27, the communication system had been mostly restored in the Jinwan district.

The spatial differences in the number of keywords posted effectively reveals the resilience of each district after the disaster. On August 23, the number of keywords in Jinwan district was greater than in both Doumen district and Xiangzhou district, and the number of keywords in Xiangzhou district was greater than in Doumen district. In the early days of the typhoon landing, Xiangzhou district was densely populated and had many Weibo users, making it more sensitive than other districts with a small population density. Therefore, the number of people affected was large, and correspondingly the number of keywords posted was also large. In the postdisaster reconstruction stage, the number of keywords posted in Xiangzhou district and Doumen district dropped significantly, reflecting its stronger resilience. Jinwan district did not show a significant drop in the amount of data released for the keywords “power outage” and “water outage,” indicating that its power system was weak in resilience and that the reconstruction after the disaster was not satisfactory. According to the changes in the search volume of the three keywords of “power outage,” “water outage,” and “no signal,” the Xiangzhou and Doumen districts had basically resumed water supply and telecommunications signals on August 25. The water supply interruption in Jinwan district was still serious, and there were still many places where the water supply had not been restored. Compared with the restoration of the hydraulic system and the communication system, it was found that the power system was more affected and its restoration was slower than that of the other two supply systems. The power system in all districts was basically restored on August 27. It can be seen the resilience of hydropower and communication systems in Xiangzhou and Doumen districts after the disaster was significantly stronger than that in Jinwan district.

3.3. Analysis of Comprehensive Vulnerability Assessment Results of Typhoon Hato. After mining the big data of Weibo with keywords, the data of the resilience index of each district in Zhuhai was obtained, and a comprehensive vulnerability index data set was established for fuzzy comprehensive evaluation. The evaluation results are shown in Table 3.

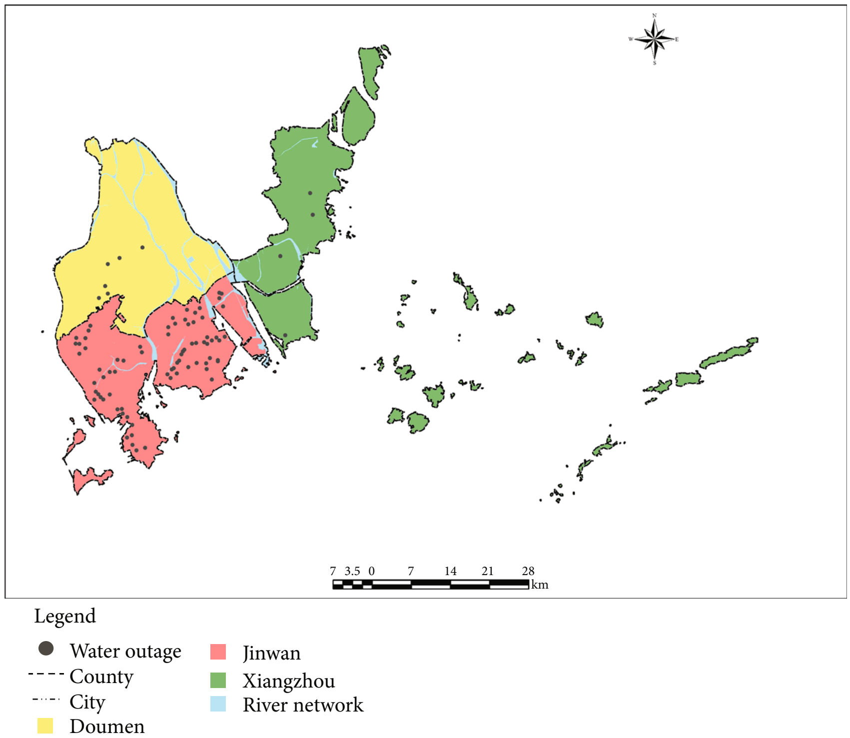


(a) August 23, 2017



(b) August 24, 2017

Figure 5: Continued.



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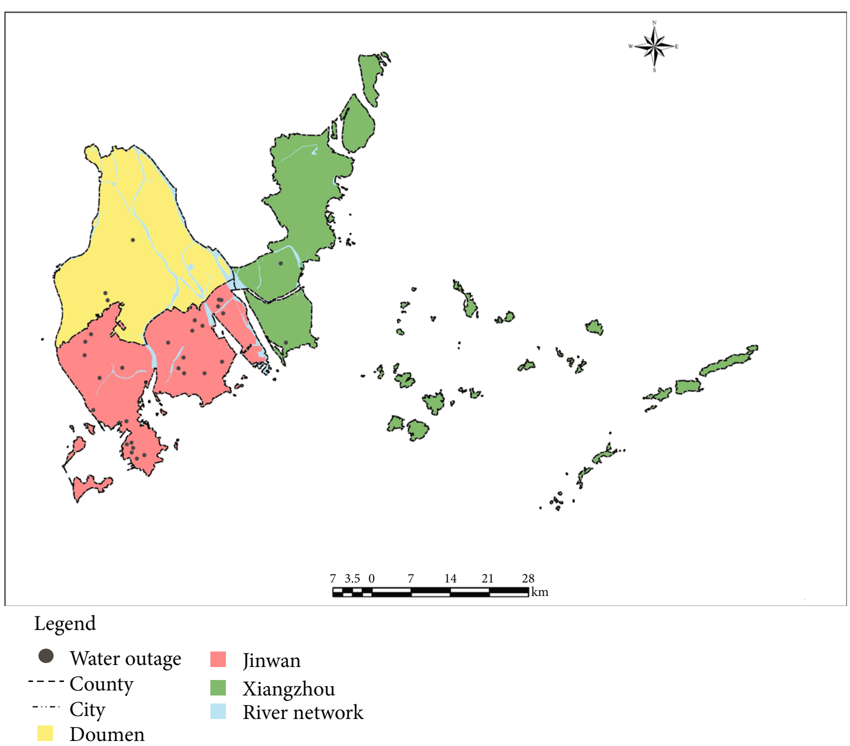

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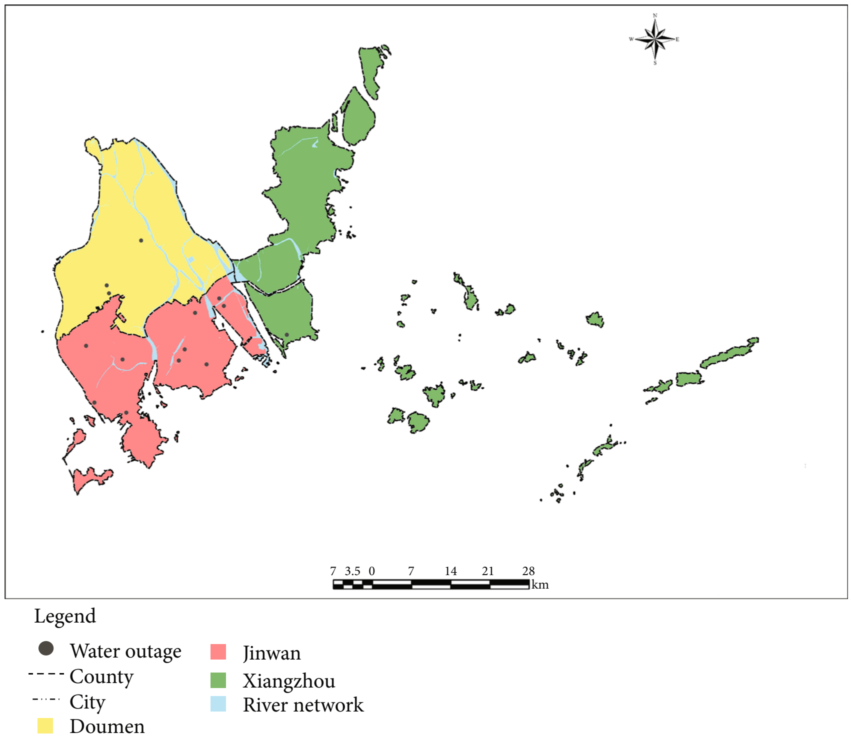
FIGURE 5: Continued.



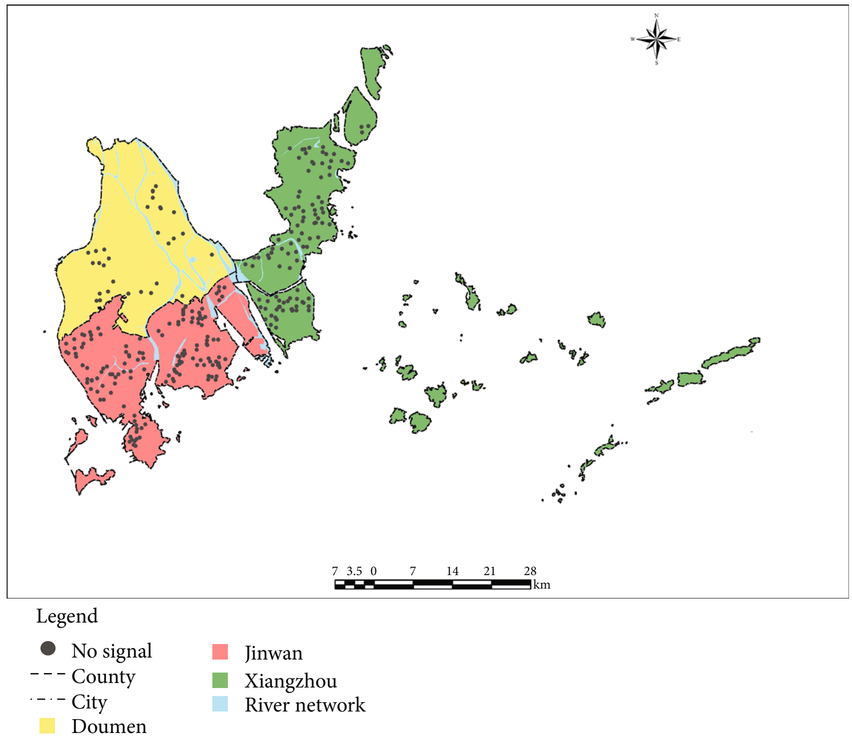
(e) August 27, 2017

Figure 5: The repair of the hydraulic system after typhoon Hato.

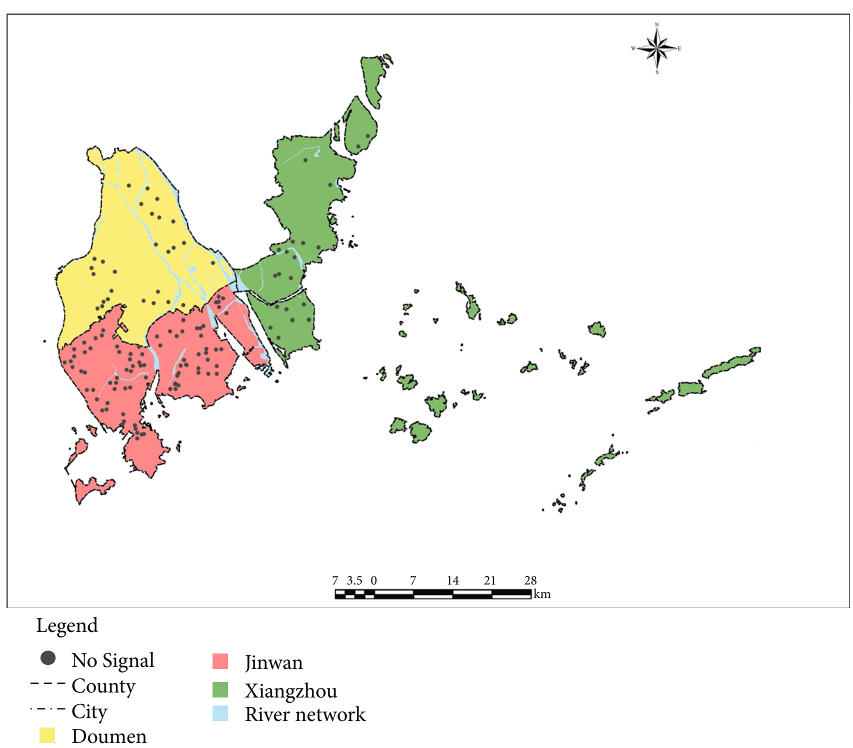
The vulnerabilities of three districts to typhoon Hato showed obvious regional differences. The overall result of vulnerability in Xiangzhou district and Doumen district was weaker, while that in Jinwan district was stronger. From the perspective of the primary indicators that affected vulnerability, the high ecological index and the low proportion of primary industry were the main reasons for the low vulnerability of the sensitivity index. The long failure time of the power supply system and the high wind speed were the indicators of resilience and exposure. The value of the rating results of exposure and response occupied two of the largest proportions in the comprehensive evaluation, which intuitively showed that the dominant factor for the different vulnerabilities of districts was the difference in coping ability and the geographical location of each districts. The general public service expenditure and per capital disposable income of Xiangzhou district and Doumen district were significantly higher than that of Jinwan district. The economy of Xiangzhou district and Doumen district were more developed, and public service investment was higher, so the response was relatively strong. Moreover, the typhoon made landfall in Jinwan district, and because Doumen district is located in the northern part of Jinwan district, Jinwan district was more affected by the typhoon. However, since the recovery speed was evaluated in several days, the differences in the results of recovery were not obvious, so further discussion and analysis should be combined with the search results of keywords.

4. Discussion

Usually, Guangdong is the province with the earliest typhoon landing time in the country and the longest typhoon impact (Local History Compilation Committee of Guangdong Province, 2001), and it had a large and rapidly developing national economy; the losses suffered were often serious. It was very important to evaluate the vulnerability of cities in Guangdong Province, which could reduce the search time in the early stage of rescue and relief work and improve the efficiency of disaster relief. By taking advantage of the immediacy, accuracy, and many users of big data, postdisaster assessment could be carried out quickly and accurately to solve the problems of inefficiency and inaccuracy in traditional assessment methods. The destruction of hydropower systems and communication systems was the most direct and obvious impact of the typhoon on the lives of people affected by the disaster. With the keyword information obtained by the comprehensive big data platform, it was clear that the public paid much more attention to water supply, power supply, and telecommunications signals than to other aspects, so the data information of hydropower and signal recovery is relatively accurate. With the help of big data, the destruction and recovery process of the hydropower system were displayed in the form of Weibo data, and its application to vulnerability assessment was beneficial to the recovery of the hydropower system. The positioning information obtained by the big data platform could clearly

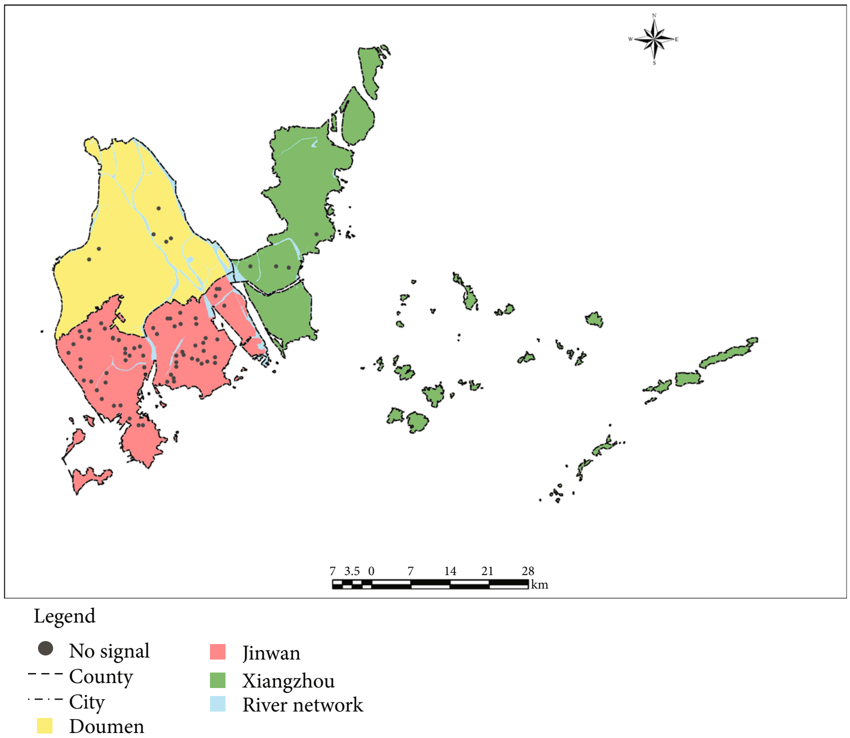


(a) August 23, 2017

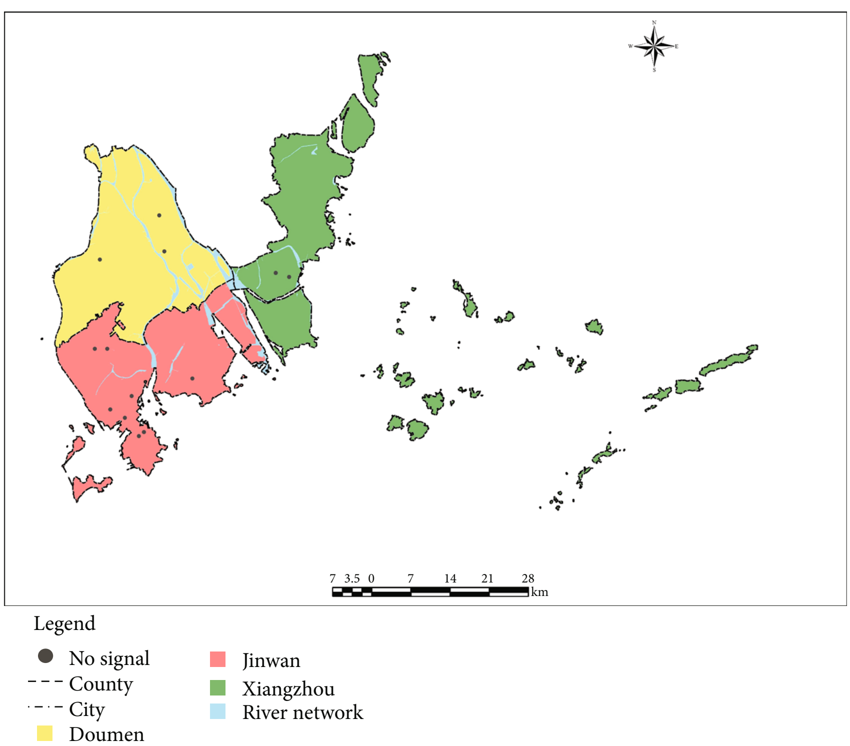


(b) August 24, 2017

Figure 6: Continued.

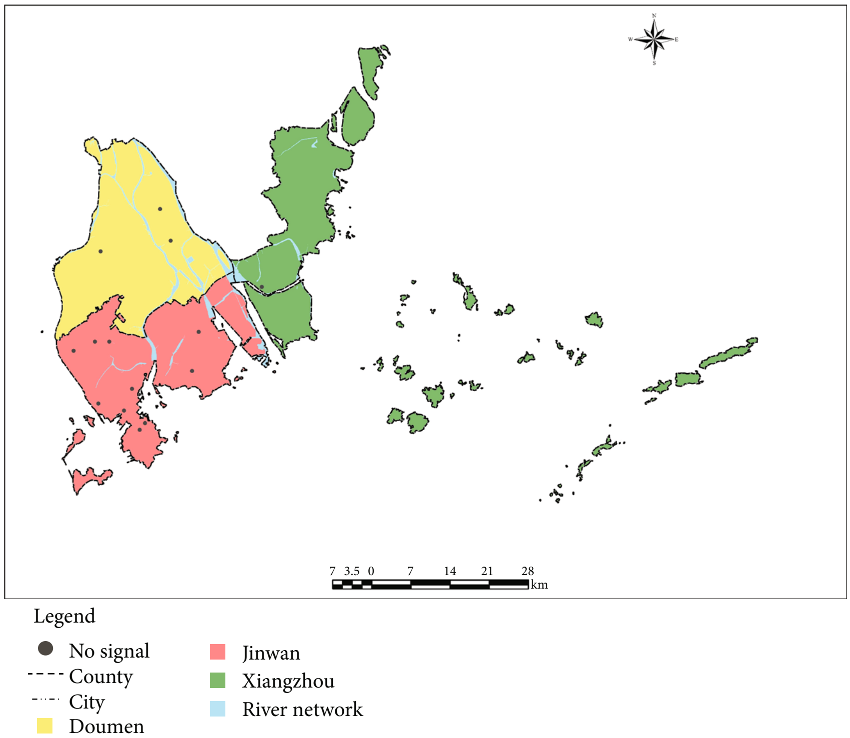


(c) August 25, 2017



(d) August 26, 2017

Figure 6: Continued.



(e) August 27, 2017

Figure 6: The repair of the communication system after typhoon Hato.

Table 3: Results of socioecological systems vulnerability evaluation in Zhuhai City.

Area (districts)	Low vulnerability level V1	Medium vulnerability level V2	High vulnerability level V3	Rating level
Xiangzhou	0.7994	0.0598	0.1407	Low
Doumen	0.3603	0.3587	0.2809	Medium
Jinwan	0.1407	0.3809	0.4783	High

show the dynamic changes of hydropower recovery, realize the visualization of the disaster recovery capabilities of different locations, and more quickly and more accurately investigate the hydropower system in the disaster-stricken area, which was helpful in guiding the postdisaster recovery work. Due to the particularity of the data source of the resilience index of this study, the accuracy of the results could reach the street level in terms of geographic location. For postdisaster recovery, a relatively refined assessment could be carried out for each district.

At present, the comprehensive risk assessment of typhoon is based on the weighted index method of index system, which evaluates the risk zoning of typhoon hazard formative factors, sensitivity of inducing environment, vulnerability of hazard bearing body, and capacity of prevent disaster, respectively, and then combines the evaluation results of the three aspects. For example, Wang et al. analyzed the typhoon disaster risk in Anhui Province, China [40]. This method paid more attention to the natural conditions of study area and lists the elevation, topographic relief, river network density, and its buffer area as indicators. Gao et al. analyzed the typhoon disaster risk in Zhuhai City, Guangdong Province, China [35]; evaluated the resilience, potential strength, and sensitivity of the typhoon, respectively; and then combined the evaluation results of the three aspects. The results of this study showed that Xiangzhou district was the strongest ecological vulnerability in Zhuhai, Doumen district was the second, and Jinwan district was the weakest, which were quite different from the results of our study, probably because the research objectives and indicators between the two studies were different. The disadvantage of the method of Gao et al. is the incompleteness of index selection. It ignored the government's response to disasters and underestimates the resilience of typhoons. The big data mining data used in this study overcame this shortcoming, because the recovery speed of the three systems reflected the efforts of the district governments for urban recovery. The government's response also reduced the harm of the typhoon to residents as much as possible, so as to improve the resilience of each district. Therefore, the system could more effectively and accurately assess the ecological vulnerability in the region. This advantage can also provide more targeted reference opinions for disaster recovery and more accurate early warning of potential urban, social, and ecological risk and even provide suggestions for urban planning.

In addition, the comprehensive evaluation results reflect the differences in small-scale vulnerabilities within cities. The overall vulnerability of Zhuhai City Centre (Xiangzhou district) is lower than that of Jinwan district and Doumen district. This is the result of the combined effects of the three systems of society, economy, and ecology. Ecological and economic systems work together on sensitivity. The lower the ecological index, the greater the proportion of primary and tertiary industries, the higher the sensitivity, and the greater the overall vulnerability. At the same time, the economic system also plays a role in response capacity. The more developed the economy, the better the infrastructure construction, the more the government spends on people's livelihood expenditures, and the greater the response capacity, the smaller the overall vulnerability. In addition, the social system acts on resilience. The faster the recovery after a disaster, the stronger the resilience, and the smaller the overall vulnerability. According to the evaluation results, economic indicators play a greater role in response than in sensitivity, while ecological indicators have a smaller impact on overall vulnerability than other socioeconomic indicators. Therefore, socioeconomic indicators are the dominant factor affecting overall vulnerability. Since Xiangzhou district was superior to Doumen district and Jinwan district in terms of percentage of primary and tertiary industries, infrastructure construction, and postdisaster recovery speed, the vulnerability of Xiangzhou district was lower than that of other two districts.

This study mainly researched the impact of typhoons on urban socioecological vulnerability and lacks connection with government emergency work. The research methods in this article can be further combined with the government's emergency work, thereby improving the efficiency of responding to disasters. There are still many aspects to be improved. For example, the research methods are how to strengthen communication with the government, how to improve the accuracy and effectiveness of relevant data, and how to intensify the availability of data. These are the problems that need to be solved in further research.

5. Conclusions

This study, based on the statistical data and the recovery speed of power, hydraulic, and communication systems collected by big data, constructs an ecological vulnerability evaluation system including exposure, resilience, response, and sensitivity. The system can quickly show the disaster situation, realize the visualization of disaster situation, and more effectively show the ecological vulnerability in the study area. This paper, taken the severely hit Zhuhai city under the background of typhoon Hato as the research object, uses big data mining technology to track the disaster, establish a vulnerability assessment model to analyze the vulnerability characteristics and reasons of urban social ecosystems under typhoon disasters, and obtain the following main conclusions. China is one of the countries most affected by typhoon disasters; typhoon Hato had a serious impact on Zhuhai, wreaking damage on the entire social, economic, and ecological system. On the basis of ecological vulnerability assessment model for typhoon disaster established by this research, our results showed the areas with the highest postdisaster vulnerability, such as Jinwan district, followed by Doumen and Xiangzhou districts. The response was the decisive factor leading to the significant differences in the vulnerability of typhoon disasters in each district. The areas with the lowest postdisaster vulnerability, such as Xiangzhou district, has a developed economy, higher regional GDP, more social security investment, and the strongest disaster response capacity. The hydropower and communication systems in Xiangzhou district and Doumen district recovered quickly. However, the recovery of hydropower in Jinwan district was relatively slow, and the ability there to withstand disasters needs to be enhanced.

Data Availability

The data are available upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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