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The Study of Temporal and Spatial Characteristics of Social-Ecological Resilience in China

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***Abstract*—*Combined with relevant literature and China's current situation in order to actively cope with the disasters caused by climate change and improve the ability of urban disaster prevention, this paper proposes the concept of "social-ecological resilience" from the perspective of ecosystem. At the same time, the social-ecological resilience evaluation index system has been constructed from three aspects: ecological stability ability, balance ability and social adaptability. The social-ecological resilience of four regions in China is measured by linear weighting method in order to the characteristics of its spatial-temporal evolution are studied. The grey correlation analysis method discusses the main influencing factors of social-ecological resilience in four regions of China. The results show that China's social-ecological resilience is on the rise in 2012-2016, but the level of social-ecological resilience in each region is uneven. The social-ecological resilience in the eastern and northeastern regions has experienced from a low to moderate process, but it difficultly enters a higher social-ecological resilience stage. The social-ecological resilience of the central and western regions has experienced three processes of low-medium-high, and the development trend is good. Urban sewage treatment rate, urban gas penetration rate and nature reserve area are the main influencing factors of social-ecological resilience in the eastern region, and the total grassland area is the common influencing factor of social-ecological resilience in the three regions of central, western and northeast.*

Keywords*—*Social-ecological resilience; China four regions; indicator system; Temporal and spatial evolution characteristics.

I. INTRODUCTION

The city is the power source of social development, an important place for the communication of political, economic and cultural activities, and a social-ecological complex system on which modern human beings rely for survival. As the global urbanization process continues to accelerate, cities are facing a variety of threats including the greenhouse effect, ecological pollution, financial crisis, terrorist attacks, and population aging. Especially cities have to deal with the challenges of climate change in the 21st century. The Intergovernmental Panel on Climate Change (IPCC) predicts that the global average temperature will rise by 2.6 °C - 4.8 °C by the end of the 21st century. At the same time, by 2100, the sea level will rise by 0.26-0.55 meters on the basis of the 2005 level (Geneva & Switzerland, 2015). It means that cities will continue to be hit by extreme weather events, and people's lives and property will be in jeopardy and social will be unrest, as global temperatures and sea levels keep rising. At present, the urbanization of China is entering a period of rapid growth, rising from 17.6% in 1978 to 57.35% in 2016 (National statistical yearbook, 2016). However, China's economy and ecological environment can't keep balances, due to the lack of reasonable and effective urban planning, construction and management. The speed of economic development far exceeds the intensity of ecological environmental protection. The direct economic loss caused by the typhoon "Mangosteen" incident in September 2018 was as high as 5.2 billion yuan (Ji Guojie, 2018). The incident reflects that China has some shortcomings in addressing climate disaster challenges, such as backward disaster prevention infrastructure, absence of emergency and response systems, and outdate warning technology. According to relevant statistics, China's annual losses due to climate change in the past decade amounted to 1,000-300 billion yuan (Zheng Guoxian, 2011). Therefore, in the context of global climate change, China has become the country with the most frequent natural disasters and the greatest losses (Wang Xiangrong & Xie Yujing et al., 2016). Under the background of accelerating global urbanization, China need to start to work from a series of supporting links such as "prevent disasters - against disasters and post-disaster restoration" and carry out related disaster prevention and mitigation actions to minimize disaster losses, so these measures will ensure people's lives and property safety and maintain social stability. Therefore, the concept of urban resilience has been come into being, which provides a new direction and a new idea for cities to solve the climate crisis (Zhang Mingshun & Li Huanhuan, 2018). How to build a resilient city and use the power of the ecology itself to improve the climate and slow down the rate of sea level rise is becoming the significant spot to which the whole citizens pay more attention.

This paper systematically sorts out various literatures about resilience and urban resilience. And then based on this, the paper clearly defines the connotation and characteristics of social-ecological resilience. At the same time, a set of feasible and representative social-ecological resilience assessment system should be established according to China's actual conditions. Next, according to the division criteria of China's economic regions (excluding Hong Kong, Macao and Taiwan), the paper divides into four regions of east, middle, west and northeast (Fig. 1) as the research objects. Firstly, eastern region The eastern region includes Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, and Hainan. Then, The central region includes Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan. Next, western regions include Guangxi, Chongqing, Sichuan, Yunnan, Guizhou, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Tibet, Inner Mongolia. At last, northeast China includes Heilongjiang, Jilin, Liaoning. After that, the paper attempts to study the

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temporal and spatial evolution characteristics of social-ecological resilience in China through the linear weighting method and grey correlation model to find out the main factors affecting China's regional social-ecological resilience. Therefore, it will provide some useful and helpful references for the construction and assessment of China's resilient cities under the background of climate change.

Fig. 1. China map.

II. Literature Review

The connotation of "resilience" has been transferred from the original engineering field to various research fields in the society nowadays. Correspondingly, various derivative concepts such as urban resilience (Bhaswati Ray & Rajib Shaw, 2018), economic resilience (Zhang Tingting,2018; Drobniak A, 2012), psychological resilience (Fletcher D & Sarkar M, 2013) and industrial resilience (Meglade J & Murray R et al., 2006) have emerged. This paper aims to study the temporal and spatial evolution characteristics of social-ecological resilience in the context of climate change, so it will focus on the concepts of resilience, resilient city and social-ecological resilience.

A. The Concept of Resilience and Holling's Works

The term "resilience" can be traced back to the Latin "resilio", that is, "return to the original state"(Wang Xiangrong & Xie Yujing et al., 2016). Subsequently, it developed into French "resilie" and English “resilience". Resilience refers to the tenacity, which covers two meanings of flexibility and resilience (Fei Xin'an & Lu Wenchao et al., 2017). In 1973, Canadian biologist Holling published his first book named *Resilience and Stability of Ecological System*, which firstly applied the term "resilience" to the field of ecology and proposed "ecology". Resilience has been defined as "the ability of an ecosystem to absorb change, sustain and restore balance after a brief shock" (Shao Yiwen & Xu Jiang, 2015). In 1996, Holling published the second book named *Engineering Resilience versus Ecological Resilience*, and made a detailed analysis between "engineering resilience" and "ecological resilience". He believes that the traditional level of "resilience" means "engineering resilience", focusing on things approaching a single stability state, and measuring the level of resilience with anti-interference and speed of maintaining balance again. The deep meaning of resilience is "ecological resilience", which mainly focuses on the dynamic stability state of things, and emphasizes that things can be converted from their own unstable system to another behaviour system after being impacted, namely entering a new stable region. In this case, the measure of resilience is determined by the magnitude of the absorption disturbance (Holling C S, 1996). In 2001, Holling published the third book named *Disruption: Understanding Transformations in Human and Natural Systems*, in which he applied the concept of ecosystem resilience to human social systems. Based on the theory of adaptive circulation, he proposed "evolutional resilience" and described the interaction between disturbance and reorganization in the complex system of society and its toughness change (Li Tongyue, 2017). It can be seen that the connotation of "resilience" has been expanding with the research field of scholar Holling, and has successively experienced "single stability of restoring the original state" to "double stability into the new equilibrium field" and then "multiple stability of the adaptive cycle."

In summary, "resilience" refers to the fact that systems can effectively absorb disturbances and restore to the original state when they are subjected to external shocks, and maintain the original structure without deformation. Subsequently, the term "resilience" is deriving a number of concepts and applied to various fields in order to meet the needs of the development of the times in the modern society.

B. The Conpect of Resilient City and International Organization

With the expansion of urban land and the rapid increase of urban population, it is expected that the global urbanization rate will reach 70% by 2050 (Wang Xiangrong & Xie Yujing et al., 2016). As a result, the relationship between various subsystems within the city is increasingly complicated, and its potential vulnerability and the risks are becoming increasingly prominent. Therefore, it is the significant point for the international organization to protect the urban safety.

In 2012, the United Nations International Strategy for Disaster Reduction launched a "Make the city more resilient" action. It put up with ten principles for making cities more resilient, which were clearly stated in the 2013 report that the construction and management of global cities will cover the consciousness of resilience to cope with natural disasters (Li Tongyue, 2017). The Resilience Alliance believes that resilient city can consume and absorb external disturbances (disasters) and keep its original characteristics, structure and key functions to normally operate. The resilient system of city covers four dimensions of technical resilience, organizational resilience, social resilience and economic resilience." (Chen An & Shi Yu, 2018). The Rockefeller Foundation of the United States gave its understanding of resilient city that as a system, entity, community or individual, the city can quickly and effectively recover after a shock and use performance indicators to describe the framework of resilient city (Sun Yang, Zhang Luocheng, et al., 2017). It also proposed "100 resilient cities·100 Resilient Cities Centennial Challenge action plan. Through the voluntary declaration of cities around the world, 100 cities are selected and provided with technical,

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resource and financial support free of charge, aiming to successfully build resilient cities and provide global urban safe examples (Fei Xin'an & Lu Wenchao et al., 2017). At present, the four cities in China (Huangshi, Yiwu, Deyang and Haiyan) have been successfully selected for this program and explore the new ways to prevent the various disasters and provides practical experiences for China to build resilient cities.

In terms of comprehensive literature (Michael Poku-boansi et al., 2018; Idowu Ajibade et al., 2017; Josune Hernantes et al., 2018), resilience cities are a new concept of urban planning, construction and development, closely related to a series of comprehensive disasters (including natural disasters and man-made disasters) with the development of urbanization. It is proposed that cities can coordinate disaster management from engineering, ecological, economic, cultural and other aspects to reduce disaster costs, when it faces these external disturbances. For one thing, the concepts of resilient city, low-carbon city, green city and ecological city are consistent. Low-carbon cities, green cities and eco-cities aim to call on governments, society and the public to pay attention to the ecological environment and promote the dynamic balance between people, cities and nature in the process of urbanization. This is in line with the ecological resilience, an essential element of a resilient city. All in all, it is the key point for these concepts to achieve the goal of the sustainable development in society. For another, the idea of a resilient city is ahead of all three for the following reasons: firstly, resilient city refers to the fact that the city can absorb the interference and maintain the normal operation of the city's basic functions based on the perspective of urban disaster prevention and reduction, when it is damaged by the ecosystem and faces a series of natural disasters. Secondly, the system has the powerful resistance when the accidents happen and learning ability after the disasters occur and continuously surpasses itself in the future development, based on sociological perspectives.

C. The Concept and Characteristics of Social-Ecological Resilience

After holling put forward the concept of "evolutionary resilience", some scholars believe that "evolutionary resilience" is equivalent to "social-ecological resilience", which refers to the development cycle of system resilience that goes through four stages: utilization, preservation, release and reorganization. It emphasized the adaptability and learning of the system (Li Gang & Xu Bo, 2018). The others think that "social-ecological resilience" is a compound term that includes urban social environment resilience and urban ecological environment resilience. Among them, urban social environment resilience is closely related to people's production and living environment. It reflects the level of urban social development through indicators such as non-agricultural employment personnel, the number of students in ordinary colleges and universities, the number of beds in hospitals and hospitals. These indicators measure the city's potential human capital and basic ability to cope with risks. Urban ecological environment resilience pays attention to the relationship between ecological environment and urbanization, and then provides the city's defense ability against natural disasters or man-made damage through the improvement of ecological environment; In turn, cities with high resilience can solve the problem of ecological environment deterioration, improve the living environment and achieve the goal of harmonious coexistence between human and nature(Zhang Mingdou & Feng Xiaoqing, 2018).

This paper focuses on the latter in the understanding of social-ecological resilience. Based on the framework system of resilient cities, "social-ecological resilience" is regarded as a subset of urban resilience. In the process of urbanization, people blindly pursue economic growth and urban expansion, the original ecosystem of the city has got to cope with the problems of frequent warming and extreme weather events. Therefore, cities need to construct a social-ecological resilience system that combines natural forces and human forces to reduce urban fragility and improve defense capabilities.

Therefore, the paper defines "social-ecological resilience" as the specific meaning that the urban ecosystem can effectively absorb and resolve the crisis when it faces natural and man-made damage. At the same time, it is necessary to use social forces to carry out ecological restoration and improve the ecological threshold after the crisis. In other words, a city's ecosystem has the following three abilities: stability, balance and social adaptability, it can be said that the city has a high degree of socio-ecological resilience. Among them, stability refers to the fact that the natural system itself can effectively absorb and solve the crisis, and the ecological environment is still in a stable state when a city is faced with disasters. For example, forests can adjust the temperature automatically through photosynthesis and keep the city at the same temperature. Balanced ability points to the fact that a city could adapt to the trend of urbanization development, find a critical value between the balance of economy and ecology, and avoid the emergence of the environmental Kuznets curve (R.C.D'Arge & K.C. Kogiku, 1973). And social adaptability means that the ecosystem can not only rely on its own strength to resolve external crises, but also use human response measures to reduce its vulnerability, such as building parks, protecting wetlands and setting up green belts.

III. Research Process and Method

A. Construct the Index System of Social - Ecological Resilience

The selection of element index in the evaluation index system is related to the correctness of the whole system analysis and evaluation, which directly affects the later research results and the recommendations based on the results. Therefore, the paper combines with the above analysis of the definition of social-ecological resilience and the contents of related references (Zhang Mingshun et al., 2018; SunYang et al., 2017; LiGang et al., 2018; R.C.D'Arge et al., 1973) to set up a social-ecological resilience evaluation index system based on the rapid development of urbanization. (TABLE I). According to a quantitative analysis of the resilience of water, air, land, vegetation and other basic natural elements from the

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three aspects of the stability ability, balanced ability and social adaptation ability of the ecosystem, we could obtain an objective level value of China's regional social-ecological resilience and then provide relevant reference for the construction of resilient cities in the future.

First, about stability indicator layer, the focus is on the ability of the ecosystem itself to withstand the crisis. Because the development of society depends on natural resources. The reasonable ecological threshold, abundant mineral resources, water resources and forest resources can not only promote the development of social economy, but also eliminate environmental pollution through ecological circulation system, Therefore, this layer selects the five elements of "coal resource reserves", "total water resources", "total grassland area", "wetland area" and "forest coverage rate" to reflect the melting amount of ecological environment. Secondly, the indicator layer of balanced capacity aims to find the balanced between economy and ecology. While pursuing economic growth, the government, society and people should establish the awareness of nature protection to avoid the road of "pollution first, treatment later". Therefore, the coordination between the ecological environment and urban development is reflected by the four elements of "urban construction land", "urban sewage discharge", "urban gas penetration rate" and "environmental pollution control investment as a share of GDP". Finally, regarding the social adaptability indicator layer, it emphasizes the subjective initiative of people with a series of environmental measures to alleviate ecological pressure and presents a benign ecological state. Therefore, "urban sewage treatment rate", "the harmless treatment rate of domestic garbage" and "area of nature reserves" reflect the importance of human ecological environment.

TABLE I. Social-ecological resilience evaluation index system.

Indicator layer	No	Feature layer	Weights
Stability	S_1	Coal resource reserves	0.083
	S_2	Total water resources	0.083
	S_3	Total grassland area	0.083
	S_4	Wetland area	0.083
	S_5	Forest cover rate	0.084
Balanced ability	B_1	Urban construction land	0.083
	B_2	Urban sewage discharge	0.084
	B_3	City gas penetration rate	0.083
	B_4	Environmental pollution control investment accounts for the proportion of GDP	0.084
Social adaptability	A_1	Urban sewage treatment rate	0.083
	A_2	Harmless treatment rate of domestic garbage	0.083
	A_3	Nature reserve area	0.083

B. Standardization of Data

The indexes with different properties are processed by range method, and the formula is as follows:

Standardization of positive indicators: $X'_{ij} = \frac{X_{ij} - X_{ijmin}}{Xijmin_{ijmax}}$

Standardization of negative indicators: $X'_{ij} = \frac{Xij_{ijmax}}{Xijmin_{ijmax}}$

Among them, X'_{ij} is a standardized indicator value; X_{ij} is the original value.

C. Entropy Weight Method to Determine the Weight

There are many methods for the analysis of weights, which can be divided into two categories. One is subjective assignment, such as Delphi method, the other is through different types of mathematical formulas, such as principal component analysis and entropy power law. The paper uses the entropy weight method to determine the index weight (Table I) in order to reflect the objectiveness of the index weight and avoid the interference of human factors. The specific calculation steps of the entropy weight method are as follows:

(1) If there are j items to be assessed, i evaluation indicators, the original evaluation matrix is formed.

$$R= (X_{nm})\ i * j\ ,\quad P_{nm} = \frac{X'nm}{\sum_{n=1}^{j} X'nm}$$

(2) Calculate the entropy of the mth indicator e_m :

$$e_m = -k \sum_{n=1}^{j} P_{nm} \cdot ln\, p_{nm}$$

(3) Calculate the entropy weight of the mth indicator Z_m :

$$Z_m = (1 - e_m) / \sum_{n=1}^{i} (1 - e_j)$$

D. Social-Ecological Resilience Comprehensive Score

The linear weighting method could determine the various factor-level indicators of social-ecological resilience. The scores of social-ecological resilience of each region are calculated:

$$W = \sum_{i=1}^{n} W_{ij} X'_{ij}$$

where W denotes the comprehensive score of ecological construction in Kunming every year, W_{ij} denotes the weight of each index, and $X`_{ij}$ denotes the index data of the extreme value (Chunhong Xia& Yan Li, 2018).

E. Social-ecological Resilience Standard

At present, there are a few researches about the evaluation and standards of social-ecological resilience. Therefore, the e comprehensive score of social-ecological resilience is divided into three levels for analysis based on the existing research results (Zhang Tingting, 2018; Zhang Mingdou & Feng Xiaoqing, 2018).

TABLE II. Social-ecological resilience classification.

Low resilience	Moderate resilience	High resilience
w ∈ [0,0.4)	w∈ [0.4,0.8)	w∈ [0.8,1)

F. Grey Correlation Analysis

The grey correlation analysis is to seek the relationship between various factors through the calculation of the relational degree. It has some advantages including low requirements for the collection of sample data. Therefore, the

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grey correlation analysis method is suitable for the analysis of dynamic history. The calculation steps are as follows:

1. Using the mean method for dimensionless data

All data for a sequence is removed by the average of the series, resulting in a new sequence.

(1) Suppose there is an original sequence:

$$x_i = \{x_i(1), (2), \dots, X_i(n),\ \}, i = 0,1, \dots, m; k = 1,2, \dots, n$$

(2) Calculate the average,

$$\overline{x_i} = \sum_{k=1}^{n} x_i(k)/n$$

(3) For X_i to be averaged, so

$$y_i = \{y_i(1), y_i(2), \dots, y_i(n)\} = \left\{\frac{x_i(1)}{\overline{x_i}}, \frac{x_i(2)}{\overline{x_i}}, \dots, \frac{x_i(n)}{\overline{x_i}}\right\}$$

2. Take the difference sequence,

$$\Delta_{0i}(k) = |y_0(k) - y_i(k), \Delta_i = \{\Delta_i(1), \Delta_i(2), \dots, \Delta_i(1)\}, i = 1,2, \dots, m$$

3. Find the maximum and minimum difference between the poles,

$$\Delta_{max} = max_i max_k \Delta_{0i}(k), \Delta_{min} = min_i min_k \Delta_{0i}(k)$$

4. Calculate correlation coefficient,

$$\xi_{0i}(k) = \frac{\Delta_{min} + \rho\Delta_{max}}{\Delta_{0i}(k) + \rho\Delta_{max}}, \rho \in (0,1), i = 1,2, \dots, m; k = 1,2, \dots, n$$

5. Calculate relevance,

$$\gamma_{0i} = \frac{\sum_{k=1}^{n} \xi_{0i}(k)}{n}, i = 1,2, \dots, m; k = 1,2, \dots, n,$$

$\rho = 0.5$.

IV. Research Results and Analysis

This paper obtains relevant data by consulting *China Environmental Statistics Yearbook*, *China City Statistical Yearbook* and regional government portals to ensure the reliability of data sources and persuasive results.

A. The Temporal and Spatial Evolution Characteristics of China's Regional Society-Ecological Resilience

According to the linear weighting method, the social-ecological resilience level of 31 provinces, municipalities and autonomous regions (excluding Hong Kong, Macao and Taiwan) can be quantified, which can directly reflect the total value of the comprehensive evaluation of the level of social-ecological resilience in the four regions of east, central, west and northeast in 2012-2016.Therefore, the dynamic evolution characteristics of the social-ecological resilience in the four regions can be obtained (Fig. 1).

It can be seen from Fig. 2 and Table II that the social-ecological resilience levels of the four regions of China are different from 2012 to 2016. First of all, regarding the eastern region: (1) The comprehensive scores of social-ecological resilience continued to increased from 0.33 to 0.67, with an average annual increase of 62.21%. It mainly related to the level of regional economic development. As the eastern region is the most prosperous region of China's economy, it includes Beijing, Shanghai, Guangzhou and Shenzhen. they have a more mature emergency response mechanism, when the disaster comes. (2) The level of social-ecological resilience in the eastern region was in a low level in 2012.

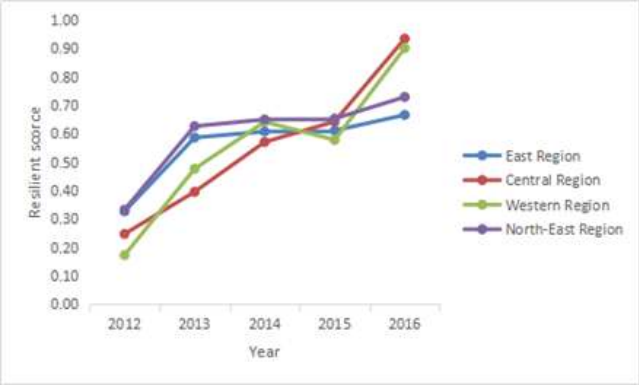

Fig. 2. China's regional social-ecological resilience comprehensive score.

After 2013, it has been in a moderate resilient stage, but it is still difficult to enter a stage of high social-ecological toughness. There are two main reasons for this. On the one hand, with global warming and extreme weather, coastal areas are much more affected by natural disasters such as storm surges, typhoons and floods than inland areas, the eastern region is more dangerous to suffer from these disasters than other regions. On the other hand, in the process of rapid urbanization in the eastern region, most of cities in eastern region lack of rational industrial layout and blindly pursuit of urban land expansion and sacrifice of ecological environment to develop the economy in the long-term. Therefore, citizens now face with the terrible living environment such as smog and sandstorms. Secondly, the social-ecological resilience of the central region rose linearly and the scores have increased from 0.25 to 0.93 from 2012 to 2016. Meanwhile, it has experienced the low-medium-high stages. The beneficial trend is due to the rich natural resource endowment and good economic development momentum in the central region. According to the collected data, the central region has the highest coal resources, rich total water resources and grassland area. The good ecological environment provides a rich material foundation for the development of the central region. The central region attaches importance to the balance between ecology and economy. The management and control of pollution of government is extremely strict and a large amount of funds has been invested to protect the ecological environment. Thirdly, about the western region. (1) In 2012-2016, the level of social-ecological resilience in the western region showed a wave-like trend. During the study period, although the scores of social-ecological resilience have increased from 0.17 to 0.90, the social-ecological resilient evaluation value decreased in 2015. Meanwhile, the resilience development rate was not balanced. The reason is that the western region has a weak economic foundation and is affected by geographical location. It is a high-risk area with frequent occurrence of geological disasters such as soil erosion, mudslides and earthquakes. In particular, a 6.5-magnitude earthquake occurred in Ludian, Pishan, and Ding of the western arears in 2015. Therefore, it is impossible to adopt scientific and reasonable emergency measures to implement self-repair and self-improvement, which largely depends on external rescue, resulting in large fluctuations in social-

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ecological resilience levels when disasters frequently invade the western region. (2) The social-ecological resilience of the western and central regions tends to coincide after 2015. In addition, the moderate social-ecological resilience stage has entered a stage of high social-ecological resilience, achieving a qualitative leap. This is closely related to China's national development policy system. The center government in China implements the "Western Development Strategy", continuously optimizes the urban spatial structure and explores new planning concepts for disaster prevention and mitigation in the western region. A series of related measures improve the level of the western resilience. Finally, the scores of social-ecological resilience of northeast region has been increased from 0.33 to 0.73 from 2012 to 2016. It experienced two stages: low and moderate social-ecological resilience. It is also difficult to enter the stage of high resilience. Its development history and reasons are similar as eastern region. The traditional northeastern region is dominated by industry and the industrial structure tends to be decentralized. In the process of pursuing economic growth, the limited resources and the importance of the ecological environment have been neglected, resulting in the current exhaustion of resources, serious air pollution, and economic loss of vitality. With the country's strategy of "revitalizing the old industrial bases in Northeast China", the Northeast region has taken advantage of population, policies, infrastructure, location and other advantages to actively explore the development space and potential to continuously strengthen self-recovery.

B. The Main Factors Influencing the Measurement of China's Regional Social-Ecological Resilience

Through the gray correlation analysis method, the social-ecological resilience and influencing factors of China's four regions in 2012-2016 were analyzed to further explore the main factors of China's regional social-ecological resilience (Table III).

TABLE III. Social-ecological resilience classification.

No.	Eastern Region	Central Region	Western Region	Northeast Region
I	B_4	S_3	S_3	S_3
II	B_2	S_1	S_5	S_4
III	A_2	S_4	S_2	B_2
IV	A_1	S_5	S_4	S_5
V	S_5	B_2	A_2	B_1
VI	S_4	A_2	B_2	A_3
VII	B_3	B_4	A_1	S_1
VIII	S_2	A_1	B_1	B_4
IX	B_1	B_1	S_1	A_2
X	S_3	A_3	B_4	A_1
XI	A_3	B_3	A_3	S_2
XII	S_1	S_2	B_3	B_3

It can be seen from Table III that the correlation between various evaluation indicators and social-ecological resilience in different regions has similarities and differences. First, the three indicators with the highest correlation of social-ecological resilience in the eastern region are urban sewage treatment rate (B_4), urban gas penetration rate (B_2) and nature reserve area (A_2); second, the three indicators in central region with the highest correlation are the total grassland area (S_3), coal resource stock (S_1) and wetland area (S_4); third, the highest indicators with the social-ecological resilience in the western region are the total grassland area (S_3), forest coverage (S_5) and total water resources (S_2). Fourth, the three indicators with the highest correlation in northeast region are total grassland area (S_3), wetland area (S_4) and urban gas penetration rate (B_2). Based on the analysis results of four regions, it can be seen that: (1)Since most of the eastern regions are located along the coast, the amount of ecological resources such as grasslands, forests, and wetlands is relatively small compared with the other three regions. The ecological stability of social-ecological resilience in the eastern region is insufficient, relying mainly on social balance and adaptability to resist disasters, and has strong social dependence. In the future, the eastern region should enhance regional economic vitality and innovation, improve the hardware facilities for urban disaster prevention and mitigation, and carry out ecological measures of diversity. (2) Grasslands of social-ecological resilience in the central, western and northeast regional plays a key role in strengthening the social-ecological resilience. Therefore, the government should take more active measures to protect farmland to grassland. (3) central, west and northeast areas are rich in natural resources. In terms of social-ecological resilience, it relies mainly on its own ecosystem to resist disasters and has strong ecological stability. In the future construction of resilient cities, we must make full use of natural ecological advantages, closely integrate regional development and ecological protection. (4) social-ecological resilience in the central、western and northeastern regions lack of the enough ability of balance and adaptability. The reasons are mainly related to the regional economy. The economic development promotes the progress of the city, and the progress of the city brings about continuous improvement of urban municipal facilities, emergency equipment, and medical facilities. In a word, the three regions must rely on national policies to develop the economy and optimize the industrial structure. The ability of disaster prevention will be improved.

V. CONCLUSION

The social-ecological resilience provides new directions and new ideas for global disaster reduction and prevention. This paper first clearly defines the concept of "social-ecological resilience" and considers that social-ecological resilience is a trait of urban development. When the ecosystem faces natural and man-made damage, it can combine its own strength with social forces to effectively combat the crisis. Secondly, based on ecological stability, balanced and social adaptability, the social-ecological resilience evaluation index system is constructed to quantitatively analyze the four regions of China's eastern, central, western and northeastern regions. Finally, based on the linear weighting method and the gray correlation analysis method, the research results show that:

First, it can be seen China's social-ecological resilience is

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on the rise through the comprehensive measurement of social-ecological resilience from 2012 to 2016. The level of social-ecological resilience in the eastern and northeastern regions is closely related to the regional economy and the development of the two is similar. The level of social-ecological resilience in the central region has been rising at a constant rate. The social-ecological resilience of the western region has risen volatility. Especially, the social-ecological resilience has declined in 2015.

Second, according to the level of social-ecological resilience, it can be divided into three levels: low resilience, moderate resilience and high resilience. During the study period, the socio-ecological resilience in the eastern and northeastern regions has experienced a low to moderate level. The development of regional economies at the expense of the ecological environment is the main reason for the difficulty of entering the high socio-ecological resilience stage in the two regions. The middle and western regions have experienced three stages of low-medium-high social-ecological resilience, and the development trend is beneficial. Especially, rich natural resources, natural ecological advantages and relevant support policies issued by the state improve level of the social-ecological resilience.

Third, according to the grey correlation analysis method, it can be concluded that eastern social ecological resilience is mainly related to the balance between social and ecological capabilities and adaptability. The social-ecological resilience of the central, the west and the northeast is mainly related to the ability to stabilize the ecology.

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