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Research Article

Evolution of Urban Resilience from a Multiscale Perspective: Evidence from Five Provinces in Northwest China

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As a new idea of urban risk management, building resilient cities with the ability to resist, eliminate, and adapt to uncertain risks is of great importance to mitigate risk impacts and promote sustainable urban development. Based on the adaptive cycle model and the characteristics of an urban system, this study analyzes the resilience levels of cities, urban agglomerations, and provinces and their adaptive stages. The results show that (1) the comprehensive resilience of cities in the five provinces of northwest China is on the rise and that the differences between cities are gradually narrowing. The development stages of the urban adaptive cycle can be divided into six stages: the rapid exploitation stage, exploitation-conservation stage, stable conservation stage, conservation-release stage, development reorganization stage, and reorganization-exploitation stage. (2) The spatial distribution of the comprehensive resilience of urban agglomerations is "high in the southeast and low in the northwest," and the development stage of the adaptive cycle is consistent with its central city or central region. (3) The level of resilience varies greatly among provinces, and the development stage of the adaptive cycle is equivalent to the average level of all cities in the province and is closely related to their respective development forces and urban problems. These findings can provide reference for policymakers to formulate scientific resilience building strategies to achieve regional sustainable development.

1. Introduction

Since the 21st century, global extreme climate conditions, which make regional giant systems and cities face a variety of cumulative and sudden risks, have also increased dramatically [1]. According to the 2030 Agenda for Sustainable Development of the United Nations, about half of the world's population lives in cities, and it is expected that, by 2050, the proportion of urban population will reach 75%. Population agglomeration has a serious negative impact on urban infrastructure, education, health, safety, and other living environment and public health. In the face of various disturbances, some cities may adjust their development patterns to adapt to the changes and achieve more long-term progress, while some cities may experience stagnation or even decline due to their weak resistance ability or difficulty in solving urban problems. Therefore, cities must become resilient and be able to cope with a range of challenges in the process of urban development by resisting shocks and improving adaptive capacity [2].

Resilience Alliance, Rockefeller Foundation, UN-Habitat, UNDRR, and others have stressed the necessity of building resilient cities and applied resilience to the development practice of cities in various countries. In China, the new round of urban master planning emphasizes the need to strengthen the ability to resist risks in order to build a sustainable city [3]. As the largest developing country in the world, China's external shocks and internal pressures interact to form complex feedback and nested relationships, which seriously affect the ability of cities to withstand risk environment. Especially in the northwest, the fragile natural environment and the backward economic development level restrict each other, resulting in the insufficient ability of the city to cope with risks and interference, which limits the

sustainable development of the city. Therefore, it is urgent to clarify the evolution characteristics and measurement methods of urban resilience, which is crucial for enhancing urban resilience and promoting regional sustainable development.

Urban resilience refers to the ability of the urban system to absorb external disturbances and maintain its unique attributes, structures, and main functions [4]. As a new idea of urban risk management, building resilient cities with the ability to resist, eliminate, and adapt to uncertain risks is of great importance to mitigate risk impacts and promote sustainable urban development. In recent years, relevant studies have focused on the concept and connotation of urban resilience [5–8], qualitative analysis, and spatiotemporal patterns [9, 10] and identification of influencing factors and research progress [11, 12]. It involves climate change [13–16], disaster prevention and mitigation [1, 17], urban planning and landscape design [18–20], urban adaptive governance [21–23], and other fields. At present, the research on urban resilience is still at the level of theoretical exploration [24], and its measurement methods have not formed a unified standard [25, 26]. Most of them summarize the characteristics of resilience by establishing models, and from the perspective of research, most of them focus on economic, social, municipal facilities, ecology, and other aspects. Previous studies have also pointed out that the resilience of cities of different scales is different and that there is a cascade effect, which may affect the regional system from point to plane [27]. At the same time, there are corresponding adaptive cycles in the process of urban development, and characteristics of different adaptive stages vary greatly [28–30].

To sum up, most studies on urban resilience are calculated from the dimensions of economy, society, ecology, and facilities and rarely consider the resilience characteristics of the overall urban system, which are often the driving factors for efficient urban development [31] and can effectively promote the improvement of the urban development environment and optimization of the development path. The research scale mainly focuses on a single large scale or rapid economic development of cities and urban agglomerations, and few studies are conducted from multiscale. In addition, the typical adaptive cycle model divides the urban development cycle into four stages: exploitation, conservation, release, and reorganization [32] to explore the future development direction and potential of the city, but it only includes the urban development cycle. In fact, the development of a city is dynamic, and its evolution stage and direction depend on the characteristics of self-organization and learning adaptability that affect the resilience of the system [29, 30, 33]. In general, there are still some challenges and gaps in the research of urban resilience. In particular, it is urgent to investigate the characteristics of and differences in urban resilience and various attributes. How to eliminate this difference between cities? What is the relationship among cities, urban agglomerations, and provinces? How to judge the urban adaptive development cycle? How to put forward corresponding measures at the policy level to enhance urban resilience? Based on the above issues, this study focuses on the resilience characteristics of the urban system and constructs an index evaluation system of urban resilience from the system attributes. Taking the five provinces in northwest China as the case area, while quantitatively calculating the resilience index, the paper uses the basic characteristics of resilience and the adaptive cycle model to position the development stages of each city and further analyzes the development links from cities to urban agglomerations and from cities to provinces through scale transformation research so as to provide reference for formulating urban sustainable development policies.

2. Theoretical Basis and Research Framework

2.1. Adaptive Cycle Model. The adaptive cycle model is a resilience research model based on complex adaptive system theory (CAS), which evolves the general or linear recovery process when the system responds to interference into a complex nonlinear evolution process of continuous learning, adaptation, and self-adjustment. It explains the development state of the city through four stages of exploitation, conservation, release, and reorganization [32]. At the same time, further refining the characteristics of resilience is helpful to reveal the dynamic direction and development potential of urban development at different stages. The model believes that cities have certain resilience and can adjust themselves to benign development in the face of risky environments. Its purpose is to establish a "safe" urban system, which can not only recover from shocks but also "bounce forward" and continuously improve its performance and adaptability. Therefore, resilience is a process of positive qualitative change occurring in a city or a transformational development process formed by quantitative change accumulation. What stage a city is in and to which stage it is evolving can be determined by comparative analysis of development levels in different periods [34]. Walker et al. [35] and Folke et al. [36] also emphasized that resilience is the ability of a system to resist interference, self-organize, learn, and adapt, with obvious evolutionary characteristics.

2.2. Research Framework. The impact of the risk environment will often destroy the original relative stability of the city and break its original development path, but it will also urge the city to take countermeasures, change or optimize the original development path, change the city from a nonbenign development state to a benign development state, and realize the sustainable transformation of the city.

Urban resilience refers to the ability of the urban system to absorb external disturbance and maintain its unique properties, structures, and main functions, which can be regarded as the collection of various abilities to achieve adaptive development under disturbance. It includes the ability of a city to maintain normal functions when it meets emergencies (such as earthquakes, floods, and emergencies), to resist and quickly recover to a normal state when disturbed, and to adjust and learn to cope with future challenges [37]. Previous studies have pointed out that resilient

cities have four basic characteristics: stability, self-organization, learning adaptability, and transformability [1, 38–44]. Among them, stability is the foundation and the bearing mechanism of urban structures. It can strengthen the development framework of the urban system by continuously accumulating resources and energy and maintain the basic social functions in a certain period of time and has a relatively stable environment in the face of interference. Self-organization is the way, which requires the urban system to achieve the coordination of internal elements through self-adjustment and self-adaptation, and its own governance efficiency is often the driving force of the long-term development of the city. Learning adaptability is fundamental, and it is the innovation mechanism of the urban system. "Human" as constitute is the basic unit of the city, with strong independent initiative and the ability to adapt, be able to predict changes, and take actions according to predetermined goals. This also promotes the city to have strong ability to adapt and restructure and improve its hierarchical structure and function structure. Transformability is the purpose and the dynamic transformation mechanism of the urban system. The purpose of urban development is to improve the quality of people's life, which also requires that it should aim at "transformation." When ecological, social, economic, and political conditions are well coupled and developed, the city will naturally evolve towards a higher stage.

In addition, there are four stages of the adaptive cycle of urban development (Figure 1), with differences in resilience and development status in different stages. In the exploitation stage (r), resilience increases rapidly and the city takes the opportunity to accumulate resources, develop rapidly, and improve its competitiveness. The stability and self-organization of the urban structure increase significantly, and learning adaptability and transformability are relatively small. In the conservation stage (K), the urban resilience and attributes of the system increase slowly and even have a trend of decline, and the peak may appear in this stage. At this stage, the city develops slowly, most of the system resources are stored and utilized, and stability, certainty, and resilience are high, but resilience is close to the threshold. The system tends to mature at the current level, and the risks of structural solidification and path locking appear. At the same time, the city uses its internal intellectual capital and innovation capacity to realize adaptive governance and development through research technology, policy formulation, and management optimization so as to prepare for the city's transformation and development. In the release stage (Ω), urban resilience and all attributes show an obvious downward trend, the system is unstable, and urban problems become prominent. In the reorganization stage (α), urban resilience and various attributes showed an obvious trend of recovery, while self-organization and learning adaptability increased significantly. The system is in the period of innovation and structural adjustment, with great uncertainty.

Therefore, by extending the adaptive cycle model, this paper builds a theoretical framework for urban resilience analysis and emphasizes the role of four characteristics of resilient cities, which contribute to sustainable urban development.

3. Study Area and Methods

3.1. Study Area. The case area is located to the west of the Great Khingan and to the north of the Kunlun Mountain-Altun Mountain-Liupan Mountain in China, involving 52 cities in five provinces of Shaanxi, Gansu, Ningxia, Qinghai, and Xinjiang, including Guanzhong Plain urban agglomeration, northern slope of Tianshan Mountain urban agglomeration, Ningxia along Yellow River urban agglomeration, and Lanzhou-Xining urban agglomeration, with an area of 3.079 million square kilometers, accounting for about 1/3 of the national area, but only about 5% of the population. It borders on eight countries, is a strategic frontier of China's national interests, is of great significance to national security, and is also an important water source for the country. The area has a temperate monsoon climate and temperate continental climate. The terrain is complex, covering plateau, Gobi, desert, grassland, mountain, basin, etc. Precipitation is scarce and decreases from east to west and from south to north. The average annual precipitation in some areas is even less than 50 mm. The natural landscape showed the evolution characteristics of arable land, steppes, desert steppes, deserts, and plateaus. Ecological environment problems such as serious soil erosion and frequent sandstorms were prominent, and the radiation area expanded year by year. As an area rich in natural resources, it provides a solid foundation for China's energy security. However, the level of social and economic development is low, and there are obvious regional differences. There is growth but no development. At the same time, although it is an open gateway to the west, traffic conditions are still relatively backward, the number of hub stations is small, high-quality medical and educational resources are concentrated in provincial capital cities, and infrastructure needs to be improved. Driven by the "Belt and Road initiative" and the "Silk Road Economic Belt," the region has an extremely important economic and strategic position with a large number of ethnic groups and rich products. In 2019, the total population of the region was 103,496,800, and the per capita GDP was 52,970.73 yuan, accounting for 74.72% of the national average. Compared with 2010, the increase rate was only 0.44%, lagging behind the national level (Figure 2).

3.2. Research Method

3.2.1. Measurement of Urban Resilience. Different scholars have different standards for measuring urban resilience. Wildavsky [38] proposed six basic characteristics of the resilience system in 1988, and then, scholars decomposed resilience into four characteristic elements of resistance, recovery, adaptation, and transformation under risk shock. At the same time, some studies have also pointed out that urban resilience in the context of the risky environment is the ability of an urban system to pursue its ecological, social, and economic goals, and there is a complex relationship between it and risk factors, including urban stability, self-organization, learning adaptability, and transformability [1, 38–44]. Therefore, urban resilience can be seen as the result of the comprehensive effect of system stability, self-

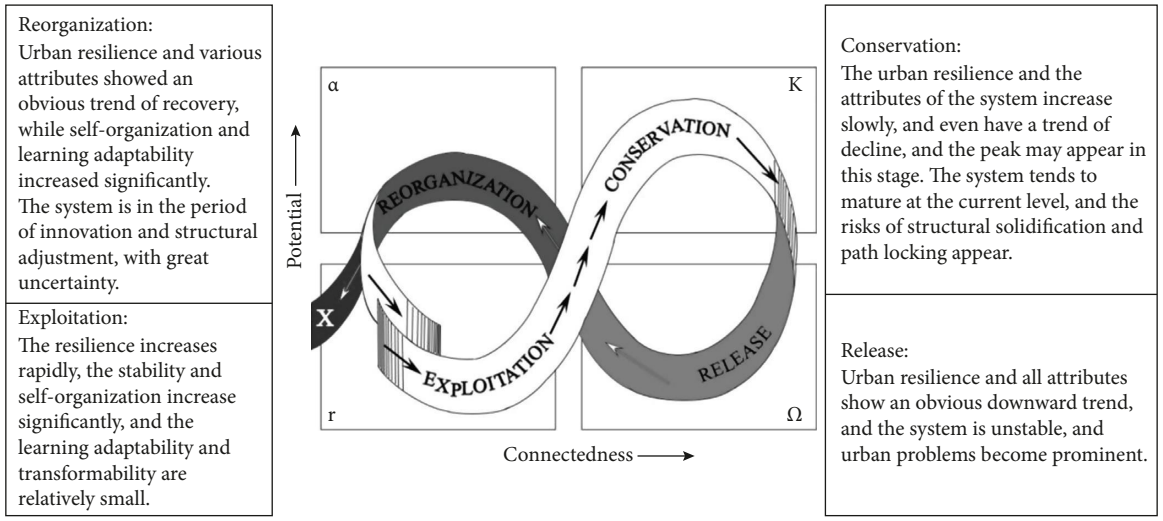

Figure 1: Adaptive cycle model.

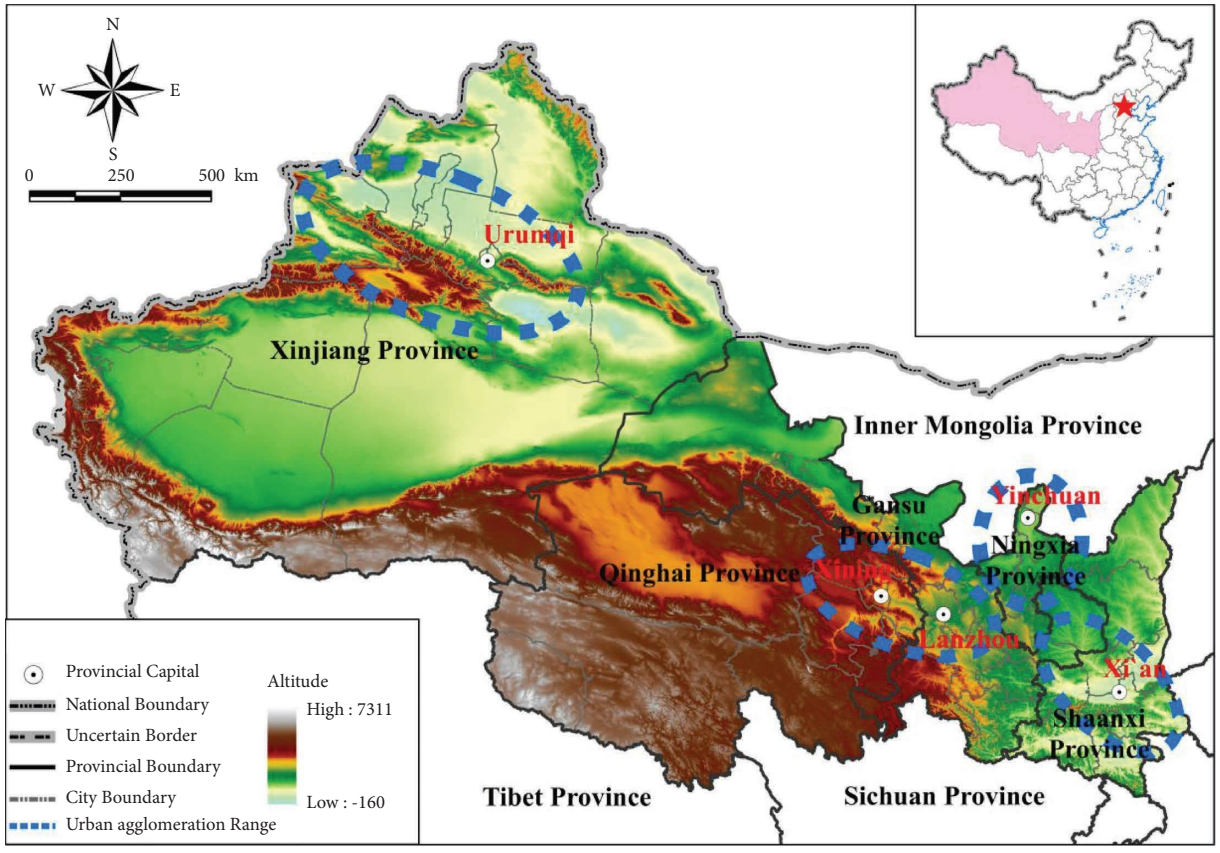

Figure 2: Study area.

organization, learning adaptability, and transformability. On the basis of fully considering the development status of cities in the five provinces of northwest China, this paper constructs the evaluation index system of urban resilience according to the urban development objectives of enhancing stability, improving self-organizing ability, strengthening adaptability, and improving transformation performance (Table 1).

Stability helps the disturbed system maintain its identity, function, and structure and is a solid foundation for urban recovery and development. Drawing on previous scholars' consideration of social ecosystem resilience [45, 46], this

Table 1: Urban resilience evaluation index system.

Target layer	Criterion layer	Factor layer	Index layer
Urban resilience	Stability	Society	Hospital beds per 10000 people, Public vehicles per 10000 people, Urbanization rate
			Proportion of the education expenditure in fiscal expenditure
			Proportion of the public service expenditure in fiscal expenditure and proportions of the urban and rural populations receiving subsistence allowances in the total population
		Economy	Per capita GDP
			Proportion of the added value of the tertiary industries in the GDP and GDP growth rate
		Environment	Regional vegetation coverage
			Good weather frequency
			Urban domestic sewage treatment rate
			Discharge standard rate of industrial wastewater and comprehensive utilization rate of industrial solid waste
	Self-organization	Population	Population natural growth rate
			Population density and registered urban unemployment rate
		Resource	Per capita cultivated land area
			Per capita construction land area and per capita daily domestic water consumption
		Capital	Investment in fixed assets of the whole society
		Information	Number of mobile phone users and number of Internet users
	Learning adaptability	Knowledge	College students per 10000 people and full-time teachers in colleges and universities per 10000 people
		Technological	Number of R&D personnel in enterprises and internal expenditure in enterprise R&D funds
			Per capita books in public libraries
		Basic environment for innovation	Per capita disposable income of urban residents
			Per capita disposable income of rural residents and proportion of science and technology expenditure in fiscal expenditure
	Transformability	Regional connectivity	Regional road network density and traffic accessibility index
		Urban form	Urban elongation
		Investment and financing level	Density of enterprises above the designated size
		Industrial structure	Advanced index and rationalization index
		Social structure	Employment increment
			Aging index and income gaps between urban and rural residents

paper also selects stability indicators from social, economic, and environmental aspects. Among them, social elements mainly provide convenient living conditions and comfortable living environments for citizens, including medical care, transportation, education, public services, and other basic aspects. Economic factors are reflected in whether the economic base can support the operation of urban superstructure, including per capita GDP and GDP growth rates. The environment is to ensure that urban activities can be carried out in a good ecological environment, including vegetation growth and the interference degree of human activities to the environment. Generally, the more sound the social, economic, and environmental factors, the stronger the city's ability to withstand the interference of emergencies.

Self-organization is the dynamic mechanism of urban development. With the acceleration of globalization and urbanization, cities are more closely connected and more and more elements such as population, resources, capital, technology, and information flow in space, thus forming the self-organizing ability of cities and influencing the spatial development mode of cities [47, 48]. Therefore, the evaluation index is selected from the material, energy, and information of the urban system, including the change of population, the allocation of resources, the amount of capital invested, and information mastery.

Learning adaptability is the embodiment of urban development potential, which focuses on the adaptability of urban recovery and the rapid response ability to actively cope with external shocks, which are the fundamental and key to urban recovery [44]. Building a learning society and an urban system with adaptive capacity is a national innovation system with Chinese characteristics in line with the law of scientific and technological development [49]. Therefore, this paper uses the ability of learning and innovation to represent the ability of a city to adapt to change at a macrolevel and selects indexes from three aspects: knowledge innovation, technological innovation, and the basic environment for innovation.

Transformability refers to the ability of a city to optimize its structure and create a "new system" when making adaptation adjustments. Two crucial characteristics of conversion capability are the ability to actively disrupt and dismantle existing systems and create and build viable alternatives [50]. Moderate city size and excellent urban structure are effective means to solve the acute impact and chronic pressure of cities [51]. Therefore, this paper respectively uses regional connectivity, urban shape, investment and financing level, industrial structure and social structure to comprehensively calculate transformability. The more convenient the connection between the city and the outside world, the larger the scale of economic development, the more reasonable the industrial and social structure, and the stronger the city's transformation ability.

3.2.2. Mathematical Analysis Model. Scholars have carried out relevant studies on the stability, self-organization, learning adaptability, and transformability of the city, respectively. Therefore, this paper adopts four common calculation methods for different features to achieve the rationality and pertinence of the final results.

(1) Stability. As a city's most direct response to disturbances, stability helps maintain the system function and structure, which is crucial for improving urban resilience. In this paper, the TOPSIS method is used to calculate stability, which is a common decision technology for multiobjective decision analysis of finite schemes in system engineering, and can analyze the gap between the system stability and ideal state [52].

(2) Self-Organization. In this paper, the entropy flow method [53] was used to measure the dissipative structure characteristics of the system to characterize the self-organization of the city. The larger the absolute value of entropy flow, the faster the city exchanges energy, material, and information with the outside world and the stronger its self-organization ability. The calculation equation is as follows:

$$S = \sum_{j-1}^{m} \left[(-1)^n \left(\frac{\left| r_j - r_1 \right|}{r_1} \right) \cdot \omega_j \right], \tag{1}$$

where S is the sum of the entropy flow generated by the system, ω_j is the weight of the index j, and $(-1)^n$ is a symbolic function. When the index exceeds the initial state, n is 1, indicating the input of a negative entropy flow, and otherwise, n is 2. Moreover, r_j is the jth index, and r_1 is the initial value.

(3) Learning Adaptability. Learning adaptability is the ability of a city to adapt to environmental changes, which helps maintain urban health and safety. The stronger the learning and adaptation capacity of a city, the stronger its resilience [1]. The calculation equation is as follows:

$$L = \sum_{j=1}^{n} r_j \omega_j, \tag{2}$$

where L is the learning and adaptability index, r_j is the jth index, and ω_j is the weight of the index j.

(4) Transformability. Transformability is a necessary condition to promote the high-quality development of a city, and the urban system can adjust its structure and realize the transformation of its social and economic status through its transformability [54]. The calculation equation is as follows:

$$T = \sum_{j=1}^{n} r_j \omega_j, \tag{3}$$

where T is the transformability index, r_j is the jth index, and ω_j is the weight of the index j.

(5) Urban Resilience. Comprehensive urban resilience is calculated by stability, self-organization, learning adaptability, and transformability. The calculation equation is as follows:

$$R = \omega_1 c + \omega_2 s + \omega_3 l + \omega_4 t, \quad (4)$$

where R refers to toughness, c, s, l, and t are the stability, self-organization, learning adaptability, and transformability after standardization, respectively, and ω_1, ω_2, ω_3, and ω_4 are the weights of four dimensions, respectively.

4. Result Analysis

4.1. Temporal and Spatial Pattern of Urban Resilience

4.1.1. Stability. From 2010 to 2018, the level of urban stability in the five provinces of northwest China showed an overall upward trend, but there were differences among different cities (Figure 3). From the coefficient of variation (Figure 4), the regional difference in urban stability levels showed a narrowing trend, decreasing from 0.2791 to 0.2513, with a decrease in 9.96%. From the perspective of spatial distribution, the overall level of urban stability showed an evolution trend of "expanding from northwest to southeast" from 2010 to 2018. Among them, high-level areas were mainly concentrated in Lanzhou city and Xi'an city, and the number showed an increasing trend, while low-level areas formed a flake concentrated distribution centered on Urumqi city. On the whole, the level of urban stability in the five provinces is shifting from low levels to high levels. The reason is that Xi'an, Lanzhou, and other surrounding urban areas have obvious regional advantages. Since the implementation of the Western Development Strategy in 2000, the level of social and economic development has increased significantly; especially, per capita GDP is about twice that of Aksu region and other low-stability cities.

4.1.2. Self-Organization. From 2010 to 2018, the level of urban self-organization in the five northwest provinces showed a general trend of shifting from low levels to high levels (Figure 5), and the index increases from 1.4 to 5.45, with an increase of 289.29%. From the coefficient of variation (Figure 4), regional differences in the level of urban self-organization tend to narrow, and the coefficient of variation drops from 0.4196 to 0.4069, a decrease of 3.03%. From the perspective of spatial distribution, the level of urban self-organization from 2010 to 2018 showed the distribution characteristics of "low in the middle and high around." Among them, high-level areas are mainly distributed in Xi'an, Lanzhou, Xining, and other urban areas and gradually gather at the southern edge, while low-level areas are mainly distributed in Bayingolin, Haixi, and other cities. The reason is that the central cities in the eastern region are clustered and have convenient transportation, and it is also the core area of urban development. The rapid exchange of population, resources, capital, and information has promoted the level of urban self-organization significantly. However, due to the restriction of natural conditions and resource endowment, the level of urban self-organization in some cities of Xinjiang always lags behind.

4.1.3. Learning Adaptability. From 2010 to 2018, the level of urban learning adaptability in the five northwestern provinces showed an obvious "Matthew effect" (Figure 6). From the coefficient of variation (Figure 4), the regional difference in urban learning adaptability shows a decreasing trend, decreasing from 1.4742 in 2010 to 1.3038 in 2018, with an overall decrease of 11.53%, indicating that all cities are making efforts to improve the level of learning adaptability, but there is still a large gap. From the perspective of spatial distribution, the learning adaptability shows regional polarization. Among them, Xi'an has the highest learning adaptability, which is 0.923, 0.8773, and 0.8508 in 2010, 2015, and 2018 respectively, leading five northwest provinces. Lanzhou, Urumqi, Karamay, Yinchuan, Xining, Baoji, and Shihezi are in the second tier. The remaining cities in the region are in the third tier, and their learning adaptability index did not exceed 0.15 in 2018. The reasons are as follows: First, provincial capital cities concentrate the higher education resources of the whole province, and high-tech industries and high-tech personnel with innovative ability will spontaneously converge to provincial capital cities. Second, individual cities have the support of national policies and the help of government agencies, so they can attract a large number of enterprises and talents to settle in. Coupled with a better urban economic foundation, learning adaptability will be improved.

4.1.4. Transformability. From 2010 to 2018, the level of urban transformability in the five northwest provinces showed obvious hierarchy (Figure 7). From the coefficient of variation (Figure 4), the regional difference in urban transformability levels shows a slow increase trend, with an overall increase of 5.23%, indicating that the gap of transformability among cities is constantly widening. From the spatial distribution, the transformability from 2010 to 2018 presents multiple "center-edge" distribution characteristics. Among them, these characteristics are more obvious in Xi'an, Yinchuan, Lanzhou, Urumqi, Shihezi as the center of the region. The reason is that the economic conditions of the central area formed around the provincial capital city are superior and that labor force and enterprises from the surrounding cities flow into the central area, which promotes the optimization of the industrial and social structure of the central city. In addition, the convenient transportation and abundant employment opportunities of the central city further aggravate the polarization effect.

4.1.5. Urban Resilience. From 2010 to 2018, the level of urban resilience in the five northwest provinces was different and fluctuated (Figure 8). From the coefficient of variation (Figure 4), the regional difference in urban resilience showed a downward trend, with an overall decrease of 10.73%, indicating that the resilience level of each city was gradually improving and the gap was gradually narrowing. In terms of spatial distribution, the resilience of each city shows the

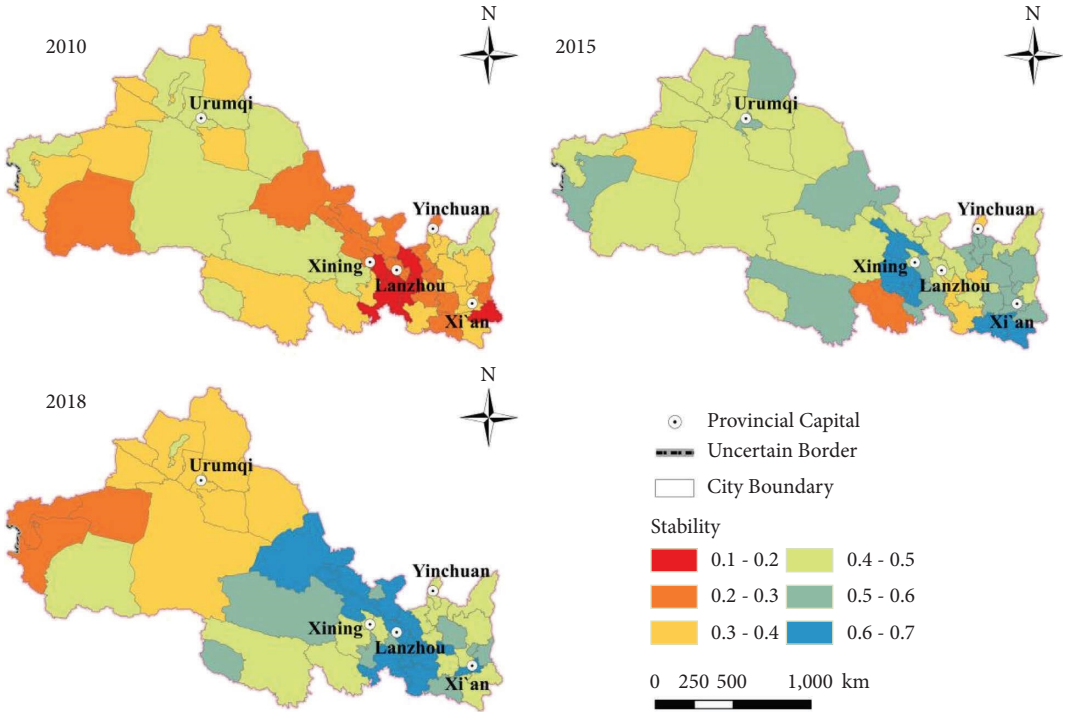

Figure 3: Spatial distribution pattern of urban stability.

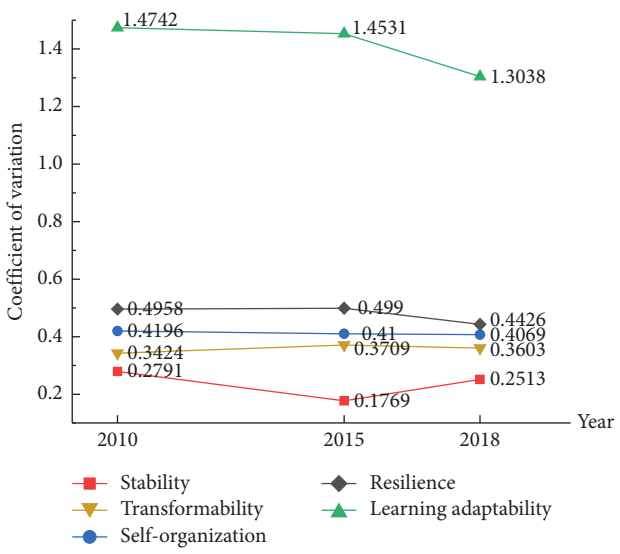

Figure 4: Variation coefficient of four attributes.

characteristics of "one super and many strong, high in the east, and low in the west." Among them, "one super" means that Xi'an's urban resilience is ahead of the whole region and plays a leading role in the whole region. "Many strong" means that Lanzhou, Yinchuan, Xining, Haidong, Urumqi, Karamay, Shihezi, and Kashgar have high resilience and can drive the development of the surrounding areas.

4.2. Variation Characteristics of Urban Agglomeration Resilience

4.2.1. Stability. From 2010 to 2018, the stability level of urban agglomerations showed two trends of a low value increase and a high value decrease (Figure 9). Among them, the stability of Guanzhong Plain urban agglomeration and the northern slope of Tianshan Mountain urban agglomeration continued to decrease, with a decrease of 27.92% and 46.36%, respectively, belonging to the high value decrease type, and the stability of Lanzhou-Xining urban agglomeration and Ningxia along Yellow River urban agglomeration kept increasing, with an increase of 69.73% and 104.16%, respectively, belonging to the low value increase type. The reasons are as follows: First, the development mode of Guanzhong Plain urban agglomeration is gradually solidified. In particular, the GDP growth rate has decreased by 57.44%, while the ratio of good air quality and public service expenditure has decreased. Second, complex natural environment and social factors limit the stable development of the northern slope of Tianshan Mountain urban agglomeration, and it is in urgent need of new development impetus to adjust the development structure. Third, while maintaining rapid economic growth, Lanzhou-Xining urban agglomeration and Ningxia along the Yellow River urban agglomeration pay attention to infrastructure construction and social security, which have great development potential and significantly improved stability.

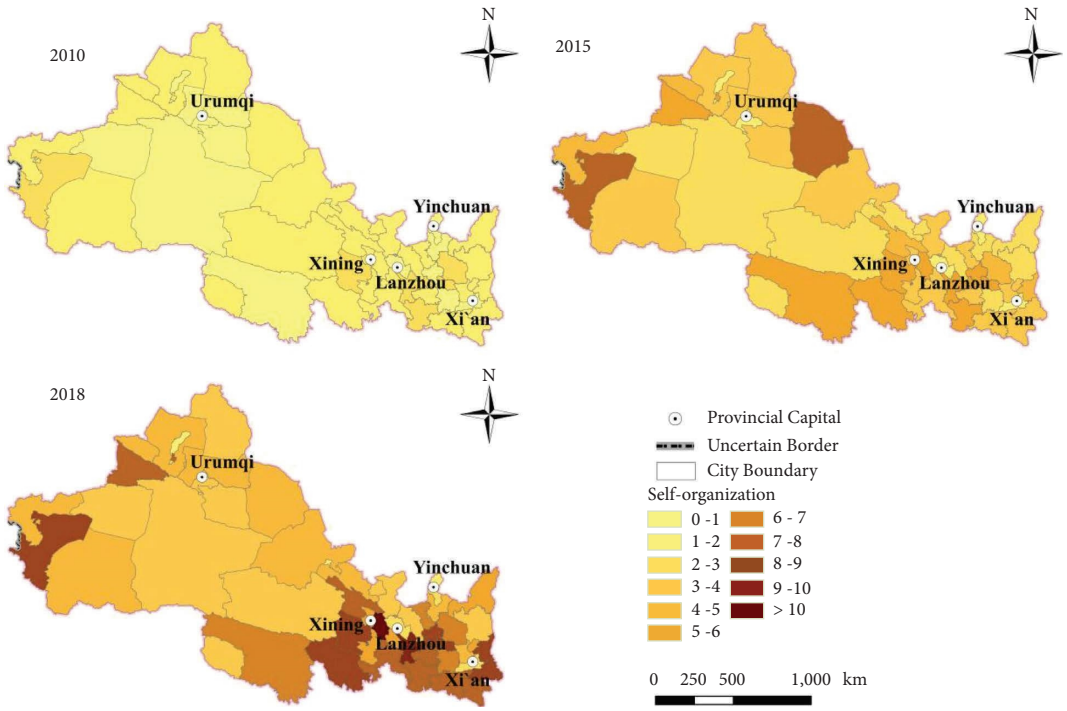

Figure 5: Spatial distribution pattern of urban self-organization.

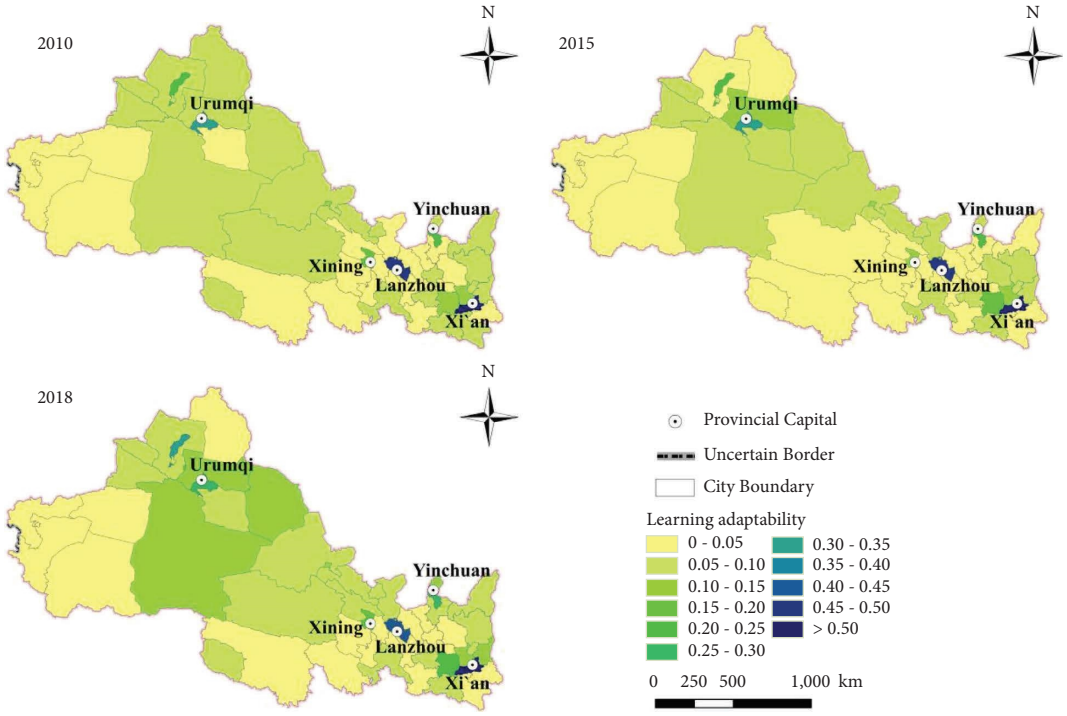

Figure 6: Spatial distribution pattern of urban learning adaptability.

4.2.2. Self-Organization. From 2010 to 2018, the level of self-organization of urban agglomerations showed an increasing trend. From the perspective of spatial distribution, the self-organization level generally shows a distribution characteristic of "high in the south and low in the north" (Figure 10). Among them, Guanzhong Plain urban agglomeration and Lanzhou-Xining urban agglomeration have a higher self-organization level (4.5785 and 4.3982, respectively) and Ningxia along Yellow River urban agglomeration and the northern slope of Tianshan Mountain urban agglomeration have a lower self-organization level (3.4533 and 3.2464, respectively). This is related to the

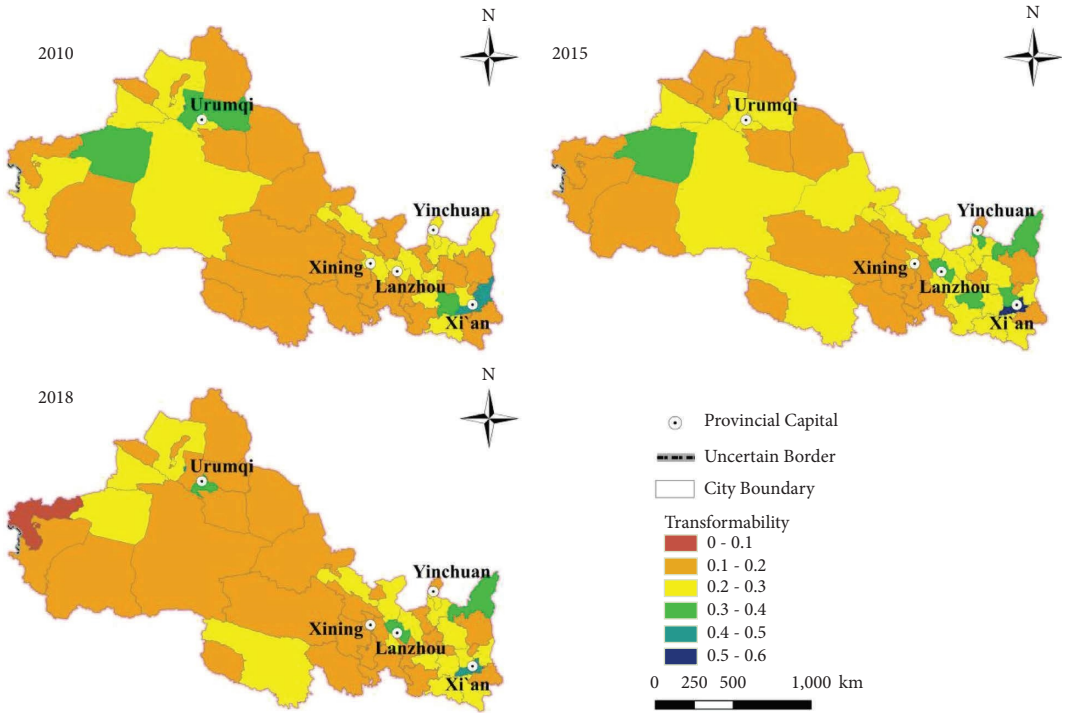

Figure 7: Spatial distribution pattern of urban transformability.

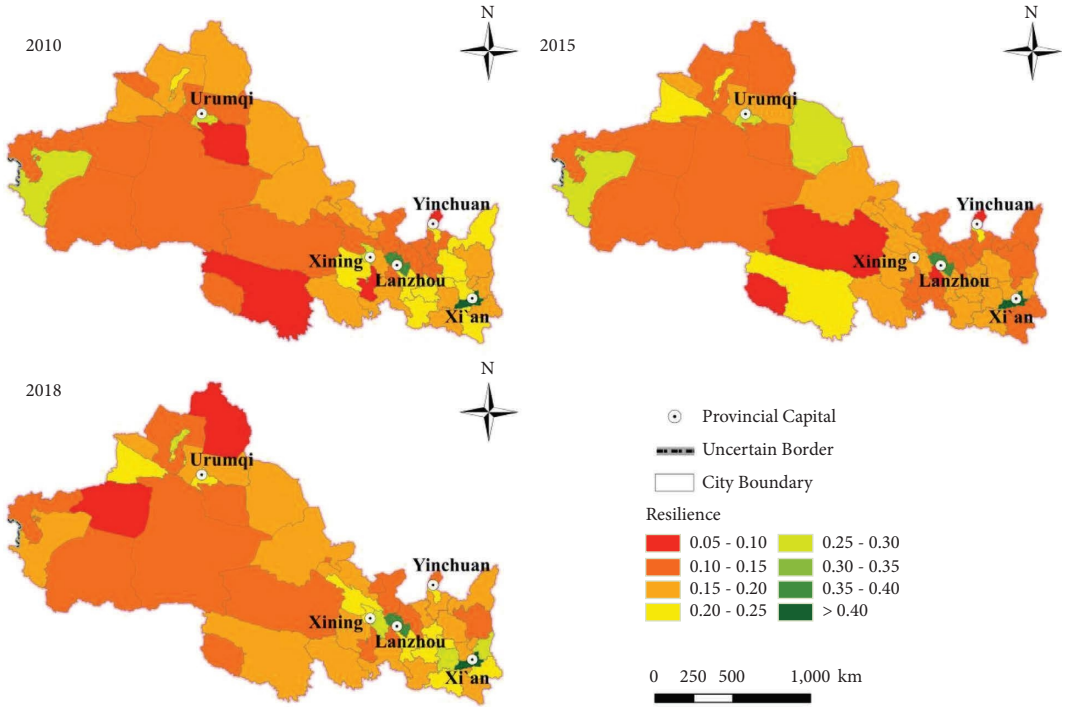

Figure 8: Spatial distribution pattern of urban resilience.

development orientation, geographical position, and national strategy of urban agglomeration. Guanzhong Plain urban agglomeration is a regional urban agglomeration in national planning and construction, which is close to the central and eastern developed areas, so it has great attraction ability. Lanzhou-Xining urban agglomeration and Ningxia along Yellow River urban agglomeration are local urban agglomerations in national planning and construction, the level of urban development is not high, but they are located in the junction of the central and northwest regions, North

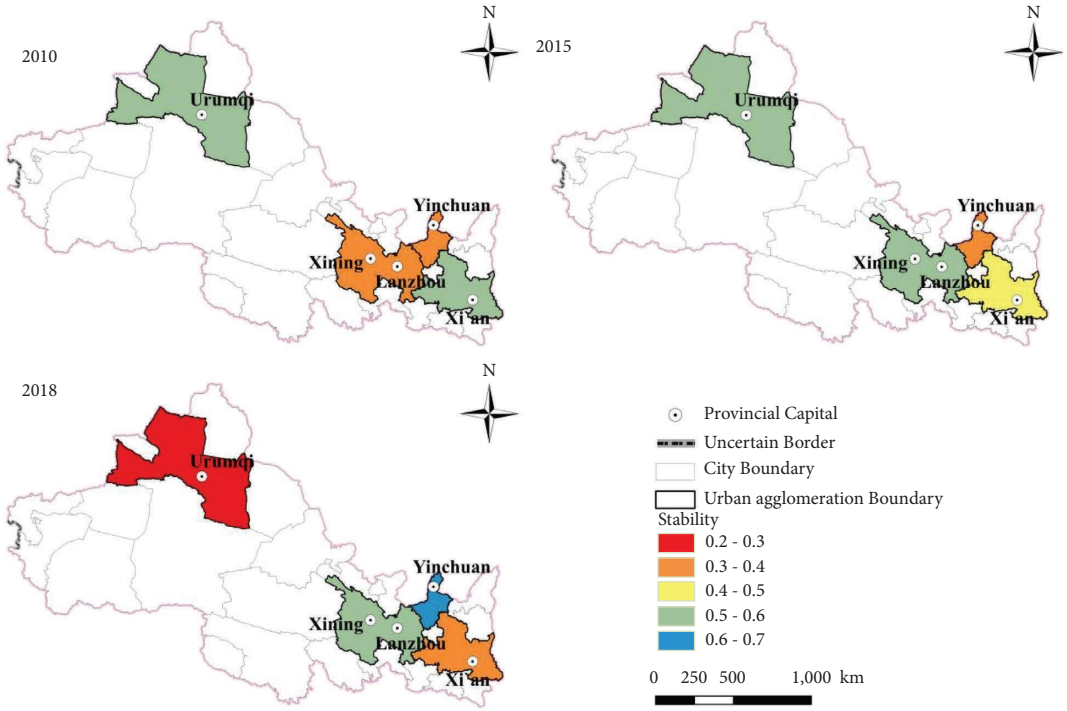

Figure 9: Spatial distribution pattern of urban agglomeration stability.

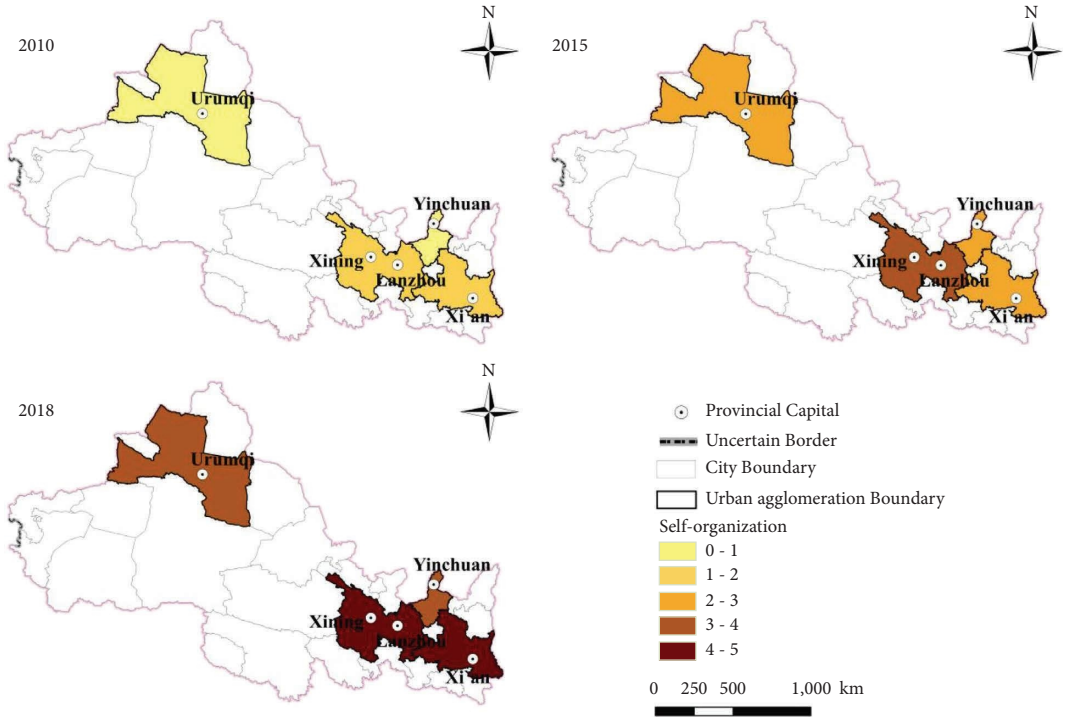

Figure 10: Spatial distribution pattern of urban agglomeration self-organization.

China, and northwest regions, and the hub has significant effects. In particular, Lanzhou-Xining urban agglomeration has accumulated more material and resources relying on the "Belt and Road" strategy. Although the northern slope of Tianshan Mountain urban agglomeration is also a regional urban agglomeration in national planning and construction, with certain attracting and gathering capacity, it is too far away from the central and eastern regions and not strongly connected with other urban agglomerations in China, so its self-organizing ability is relatively low.

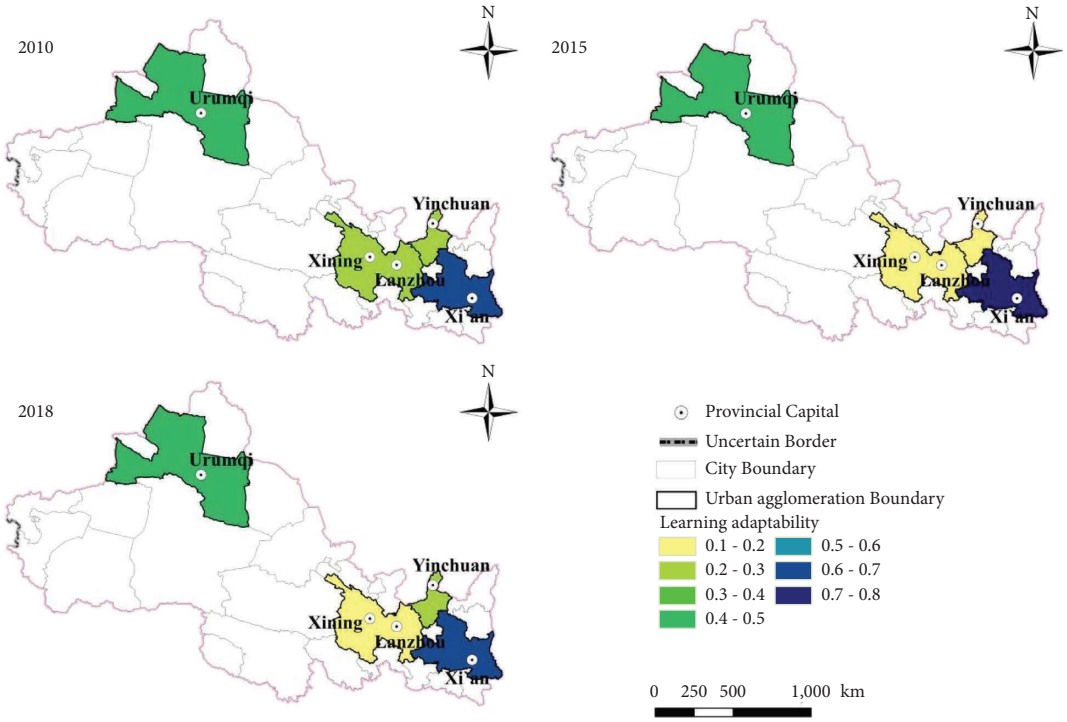

Figure 11: Spatial distribution pattern of urban agglomeration learning adaptability.

4.2.3. Learning Adaptability. From 2010 to 2018, the level of learning adaptability of the four urban agglomerations showed obvious hierarchical characteristics (Figure 11). In Guanzhong Plain urban agglomeration, universities and enterprises are densely distributed and science and technology input is large, so learning adaptability has always been in a leading position. The northern slope of Tianshan Mountain urban agglomeration is a medium area for the country to communicate with the outside world. The living standard of residents and the importance of science and technology are relatively high, so learning adaptability is in the middle level. Lanzhou-Xining urban agglomeration and Ningxia along Yellow River urban agglomeration are the lowest, but because of the loss of high-tech talents and high-tech enterprises in Lanzhou-Xining urban agglomeration, while the science and technology investment in Ningxia along Yellow River urban agglomeration increases significantly, the number of talents and enterprises is stable, so the learning adaptability of the latter exceeds that of the former.

4.2.4. Transformability. From 2010 to 2018, the transformability level of the four urban agglomerations showed two trends of increase and decrease (Figure 12). Among them, Ningxia along Yellow River urban agglomeration and the northern slope of Tianshan Mountain urban agglomeration show an increasing trend, while Guanzhong Plain urban agglomeration and Lanzhou-Xining urban agglomeration show a decreasing trend. This is related to the social structure and industrial structure of urban agglomeration. In 2018, the aging index of Guanzhong Plain urban agglomeration was 9.61%, the income gap between urban and rural residents was 20129 yuan (the highest in the whole study area), the social structure was unbalanced, and urban transformability was impaired. Lanzhou-Xining urban agglomeration is dominated by agriculture and industry. The high proportion of traditional industries for a long time has reduced the rationalization of industrial structure (by 56.52%), and the speed of industrial transformation is slow, affecting the urban transformation ability.

4.2.5. Urban Agglomeration Resilience. After comprehensive processing and calculation of the data of the four urban agglomerations, the trend chart of the resilience index was obtained (Figure 13).

From the perspective of spatial distribution, the comprehensive resilience of four urban agglomerations in the five provinces of northwest China showed a distribution characteristic of "high in the southeast and low in the northwest" from 2010 to 2018 (Figure 14). The resilience index of Guanzhong Plain urban agglomeration shows a high value and steady-state characteristic. The overall resilience has decreased by 0.03 in the past 9 years, indicating that the overall development structure of urban agglomeration is stable, but the development model is gradually fixed, which is prone to path locking, resulting in insufficient development vitality. The resilience index of Lanzhou-Xining urban agglomeration is at a medium level with a slight increase. The overall resilience has increased by 0.14 in the past 9 years, indicating that the development of urban agglomeration is in an upward phase, the stability of regional structure is being established, and population, resources, capital, and information are also flowing to this region. The resilience index of Ningxia along Yellow River urban agglomeration is the lowest, but growth is stable, with an increase of 54.01%, indicating that the development of urban

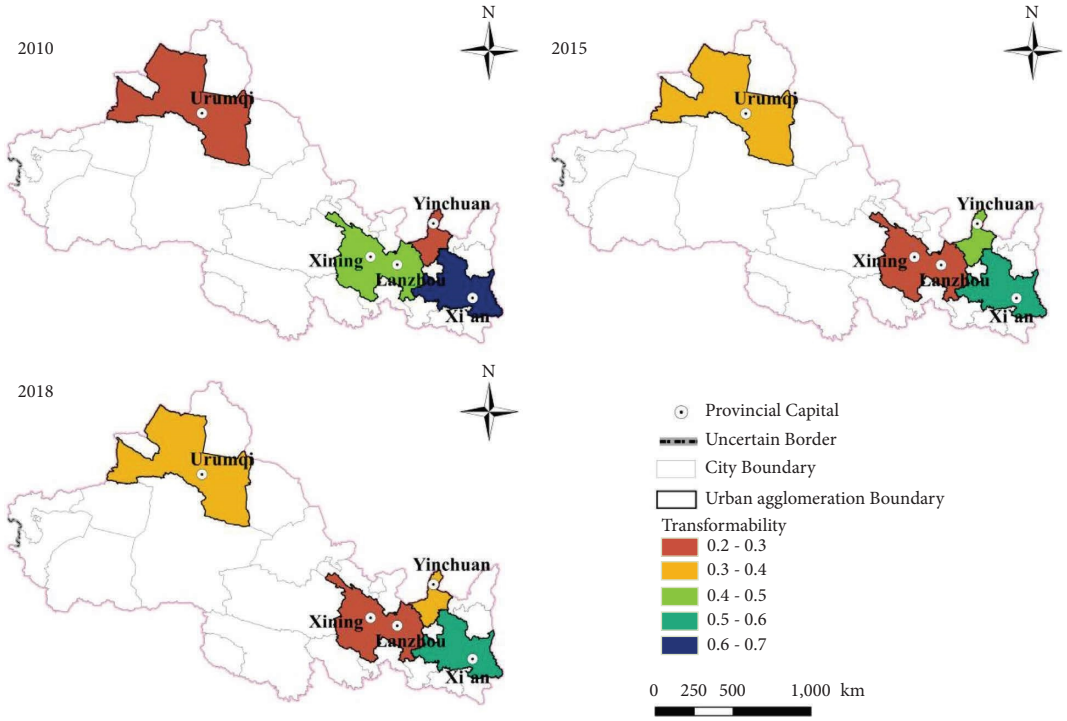

Figure 12: Spatial distribution pattern of urban agglomeration transformability.

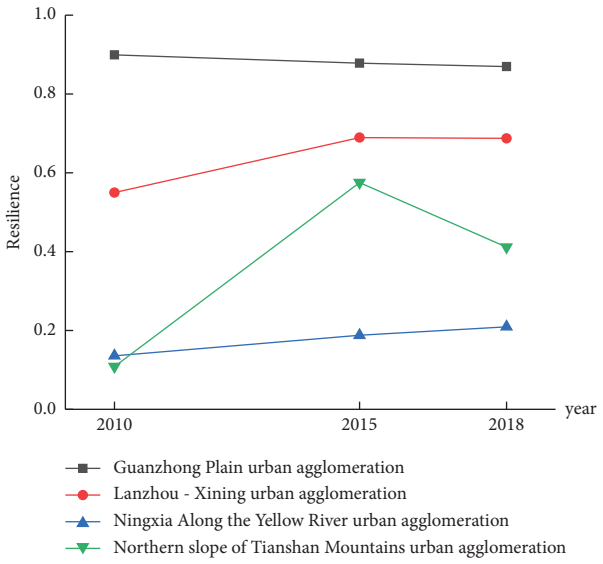

Figure 13: Variation trend chart of resilience in four urban agglomerations.

agglomeration is also on the rise at present, but the ability to attract external development factors is insufficient. The resilience index of the northern slope of Tianshan Mountain urban agglomeration increased first and then decreased, with the largest variation, indicating that the development path of urban agglomerations is uncertain and that system structure changes are complex, which is because the development of urban agglomerations is limited by the harsh ecological environment, and economic ties are not strong due to its distance from the central and eastern developed regions.

4.3. Variation Characteristics of Provincial Resilience

4.3.1. Stability. From 2010 to 2018, both stability level mutation and steady state were present in 5 provinces (Figure 15). The stability of Gansu Province increased by nearly two times, the stability of Shaanxi Province and Qinghai Province increased slowly, and the stability of Ningxia Autonomous Region and Xinjiang Autonomous Region continued to decline, with a decrease of 24.86% and 44.19%, respectively. This is related to the different development status and goals of each province. Gansu contains many national key ecological protection areas, so development is mainly coordinated and stability is growing rapidly. Shaanxi has a high level of development and has fixed development mode and certain development advantages, so the urban structure will not change basically. Qinghai mainly focuses on animal husbandry and resource development, and the ecological environment is fragile, so it is difficult to make big changes in the development mode of the whole province. At present, Ningxia develops the spatial pattern with the main traffic passage as the axis, the original development mode is broken, and stability shows a downward trend. The development of Xinjiang is mainly to maintain social stability. The development level of various cities is uneven, transportation is inconvenient, and the environment is harsh in the whole region. Therefore, the development mode of Xinjiang cannot be fixed, and uncertainty is high, so it cannot form a stable development path.

4.3.2. Self-Organization. From 2010 to 2018, the self-organization level of five provinces showed an increasing trend, especially Qinghai Province, which increased rapidly

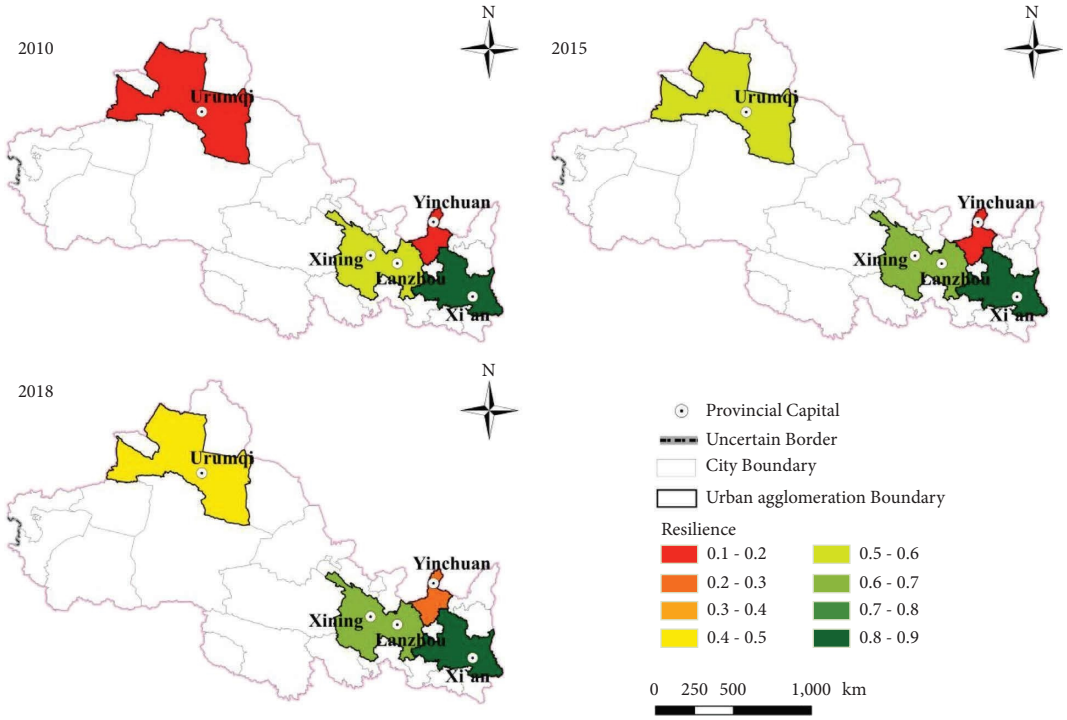

Figure 14: Spatial distribution pattern of urban agglomeration resilience.

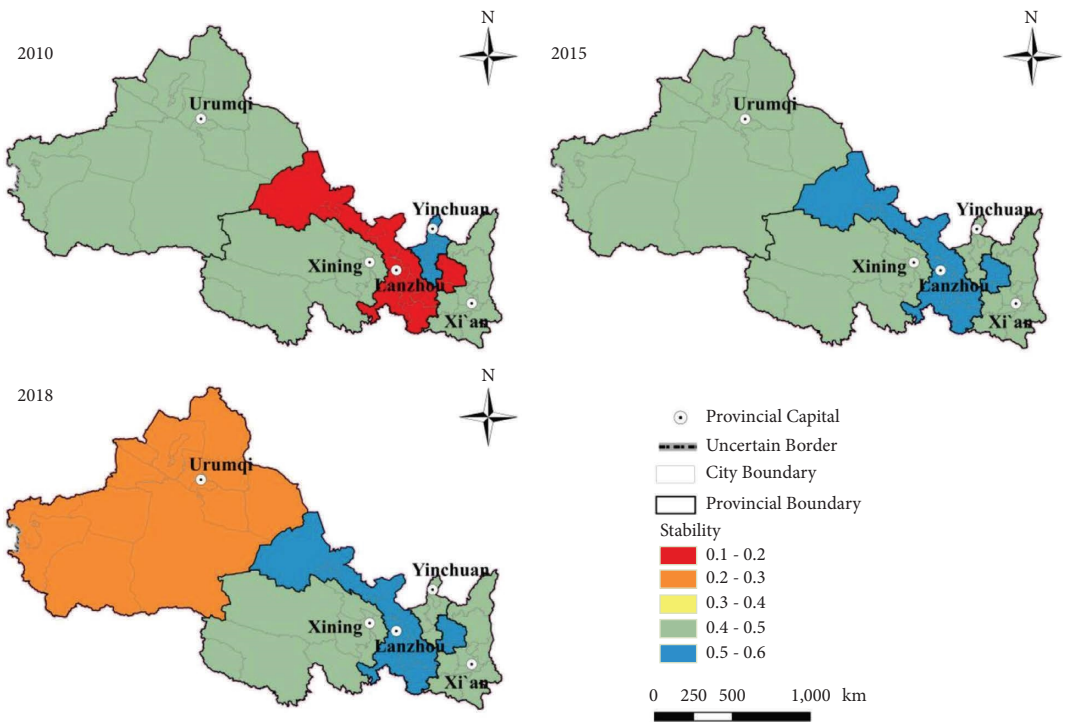

Figure 15: Spatial distribution pattern of provincial stability.

after 2015 (Figure 16). The reason for this change is that the implementation of national projects has added new development impetus to the region. The economy of Qinghai Province is mainly based on the development of animal husbandry and energy enterprises. The development mode is fixed, and the development speed is slow. Until the Lanzhou-Xinjiang high-speed railway was completed and opened to traffic in 2014, the development of cities along the line has been given an opportunity, a large number of population, resources, funds, and information have flowed in, the

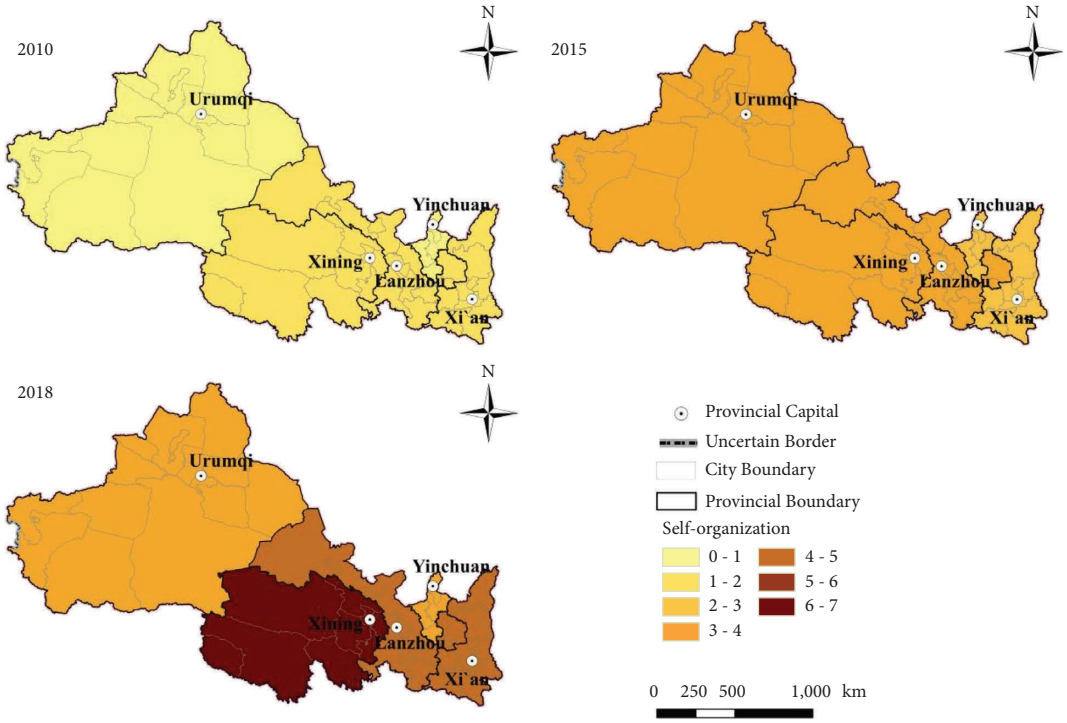

Figure 16: Spatial distribution pattern of provincial self-organization.

development of other cities in the province has been supplemented accordingly, and the development of the whole province has been activated.

4.3.3. Learning Adaptability. From 2010 to 2018, the level of learning adaptability in five provinces showed the "Matthew effect." From the perspective of spatial distribution, learning adaptation presents a distribution characteristic of "low in the middle and high in both sides" (Figure 17). Among them, Shaanxi Province is far ahead (0.717 in 2018), and the learning adaptability of Gansu Province and Qinghai Province shows a downward trend, with a decline of 11.84% and 32.06%, respectively. The reason is that the number of universities, high-tech enterprises, and high-tech talents in Shaanxi Province is the largest and steadily increasing among the five provinces in northwest China. At the same time, it has invested a lot in science, technology, and education. It has also made great efforts to narrow the gap between urban and rural areas and coordinate and unify urban and rural development so as to enhance the regional ability to adapt to interference. The scientific research environment in Gansu Province and Qinghai Province generally leads to the loss of talents and enterprises. Meanwhile, there are significant differences between urban and rural areas in the province, and disturbances and challenges cannot be transformed into "activation points" for development, resulting in problems in regional development.

4.3.4. Transformability. From 2010 to 2018, the transformability level in five provinces showed two trends of increase and decrease (Figure 18). Among them, Qinghai Province continued to decline, with a decrease of 40.98%, while other provinces showed an increase trend. This is closely related to vigorously developing regional traffic in Qinghai Province. With the improvement of transportation facilities, the tertiary industry has been fully developed, the previously solidified development model has been broken, and the industrial structure has begun to transform. At the same time, the connection between Qinghai Province and other provinces has been strengthened, and there is a phenomenon of "leaving home" population flow in the region. People either flow from second-tier cities in the province to provincial capital cities or from Qinghai Province to other provinces. This directly leads to the decrease in employment increments, the increase in aging levels, and the decrease in regional transformability.

4.3.5. Provincial Resilience. After comprehensive processing and calculation of the data of the five provinces, the trend diagram of the resilience index (Figure 19) and the spatial distribution diagram (Figure 20) were obtained.

The resilience index of Shaanxi Province shows a trend of a "high value decline," with an overall decrease of 0.2 in the past 9 years, indicating that the development model of Shaanxi Province has begun to be fixed and the development vitality of the region needs to be activated. The resilience index of Ningxia Autonomous Region shows a trend of a "low value rising," and the overall change range of the resilience index is not large in the past nine years, indicating that the province has stable development at the present stage and a clear development goal. The resilience index of Gansu Province shows a trend of a "middle value decline," with an overall decrease of 46.16% in the past 9 years, indicating that

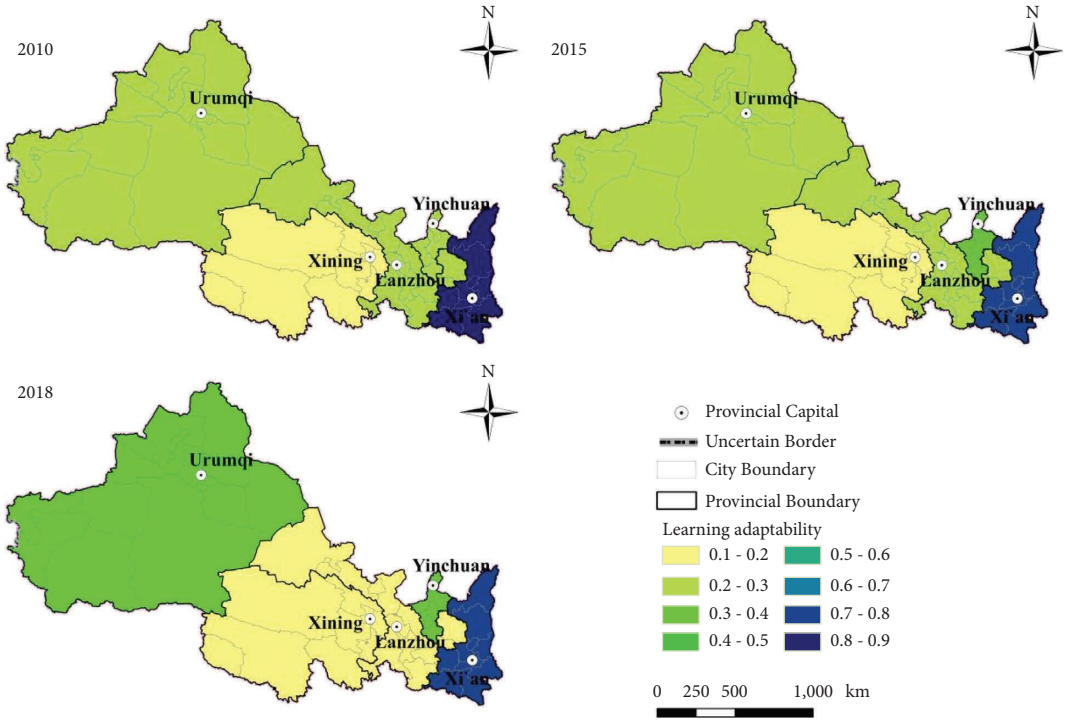

Figure 17: Spatial distribution pattern of provincial learning adaptability.

the province's development has reached a bottleneck stage and that the fixed development model can no longer meet the development requirements of the present stage, and urban problems become prominent. The resilience index of Qinghai province shows a trend of a "high value rising." The overall change of the resilience index in the past nine years is significant, indicating that the province is in an upward phase with vigorous development and good development prospects. The resilience index of Xinjiang Autonomous Region shows a trend of "low value fluctuation," which fluctuates significantly in the past nine years, indicating that the province's development structure is complex, its development model is not unified, and its overall adaptability is not strong in dealing with disturbance changes.

4.4. Multiscale Analysis of the Adaptive Cycle

4.4.1. The Adaptive Cycle of Cities. Based on the value and change rate of urban resilience and its attribute characteristics, combined with the evolutionary urban resilience model, this paper classifies the adaptive cycle of cities (Table 2). The number of cities in the stable conservation stage (K) is the largest in the region, the urban structure is highly stable, and the development path is locked. The second is the exploitation-conservation stage (r-K) and the conservation-release stage (K-Ω). The former city belongs to the rising stage of development, while the latter city cannot meet the needs of new changes due to the emergence of urban problems. The cities in the development reorganization stage (α) are the least, the resilience index of these cities has recovered, and the future direction and development content of cities are being determined.

4.4.2. The Adaptive Cycle of Urban Agglomerations. There are differences in the adaptive cycle of urban agglomerations in the five provinces of northwest China. From 2010 to 2018, Guanzhong Plain urban agglomeration has a high resilience index, decreasing stability, high self-organization, and little change in learning adaptability and transformability, indicating that it is in the stable conservation stage (K). Among them, Xi'an is the central city of the entire urban agglomeration, which together with Xianyang City and Xi'an-Xianyang New District constitutes the core development circle of the entire urban agglomeration. Baoji city and Tianshui city are located on the main axis of urban agglomeration development, with high-tech industrial parks, which are the driving force of urban agglomeration development. The resilience index of Lanzhou-Xining urban agglomeration increased slightly, stability showed an increasing trend, self-organization was high, and learning adaptability and transformability decreased slightly, indicating that the urban agglomeration structure tended to be stable and that it was in the exploitation-conservation stage (r-K). Among them, Lanzhou city and Xining city are located in the center of the urban agglomeration. Haidong City has frequent input and output of population, resources, capital, and information and has great potential for urban development, which provides an opportunity for development. Other cities have a low overall development level and need the trickle-down effect of the central city to drive development. The resilience index of Ningxia along Yellow River urban agglomeration is low, but the growth rate is fast, and stability continues to rise, the growth rate is large, self-organization shows an increasing trend, learning adaptability is stable, and conversion increases slowly, indicating

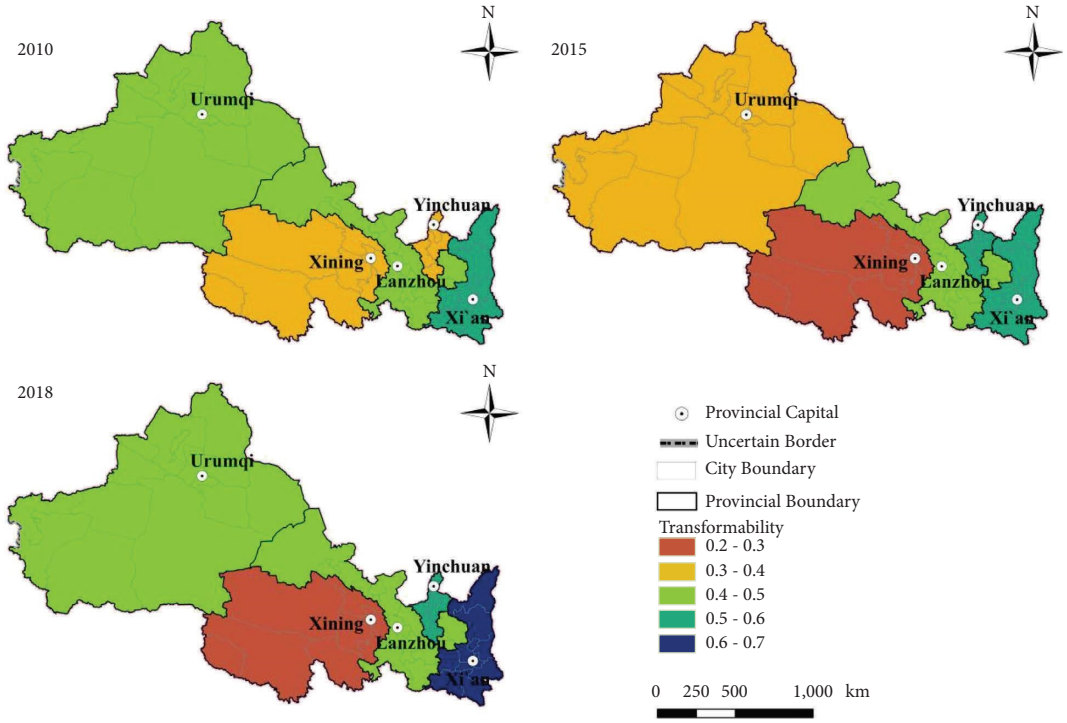

Figure 18: Spatial distribution pattern of provincial transformability.

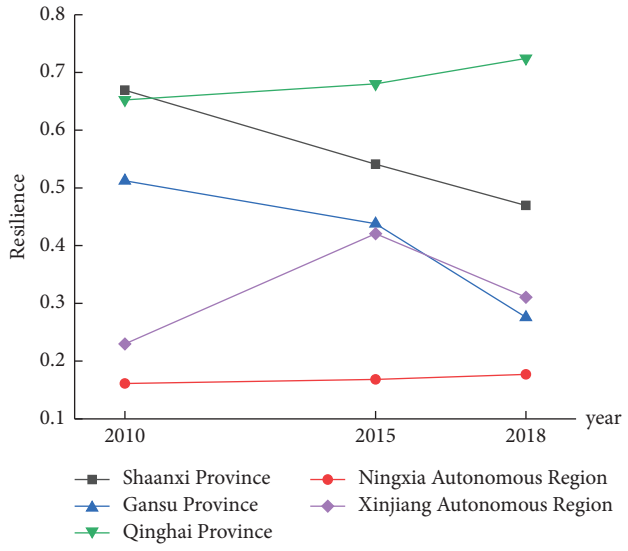

Figure 19: Variation trend chart of resilience in five provinces.

that it is in rapid exploitation (r). Among them, the urban circle jointly constructed by Yinchuan city and Wuzhong city is the core development area of the entire urban agglomeration. Shizuishan city and Zhongwei city are the two subcentral cities of urban agglomerations, which are closely connected with the central area to jointly support the development of urban agglomerations. The resilience index of the northern slope of Tianshan Mountain urban agglomeration first increases and then decreases, with a large range of change and a continuous decrease in stability, but the self-organization growth rate is fast, learning adaptability is high, and transformability shows an increasing trend. The unstable development structure of urban agglomerations shows that it is in the stage of development reorganization (α). Among them, Urumqi and Changji city formed the urban circle which is the development core of the entire urban agglomeration, and other cities along the "Silk Road" economic belt constitute the development axis of urban agglomerations, but the agglomeration effect is low, and the phenomenon of industrial similarity is serious, resulting in the overall development of urban agglomeration being unstable. It can be seen that the central city or central region of urban agglomerations plays a leading role and that the adaptive cycle stage of urban agglomerations is consistent with the central city or central region.

4.4.3. The Adaptive Cycle of Provinces. There are differences in the adaptive cycle of five provinces in northwest China. From 2010 to 2018, Shaanxi Province's resilience index was high, stability grew slowly, and self-organization was high, but its growth rate was slow, and learning adaptability and transformability tended to be stable, indicating that it was in the stable conservation stage (K). Most of the cities under the jurisdiction of Shaanxi Province are also in the stable conservation stage, with agriculture or energy industry as the main industry, have slow industrial transformation, and have lack of new driving force for development. However, there are some cities that realize rapid industrial structure transformation by a high-tech industry, such as Xi'an, Xianyang, and Baoji, which play a driving role in the development of Shaanxi Province. The resilience index of Ningxia Autonomous Region was small but showed an upward trend, stability continued to decline, self-

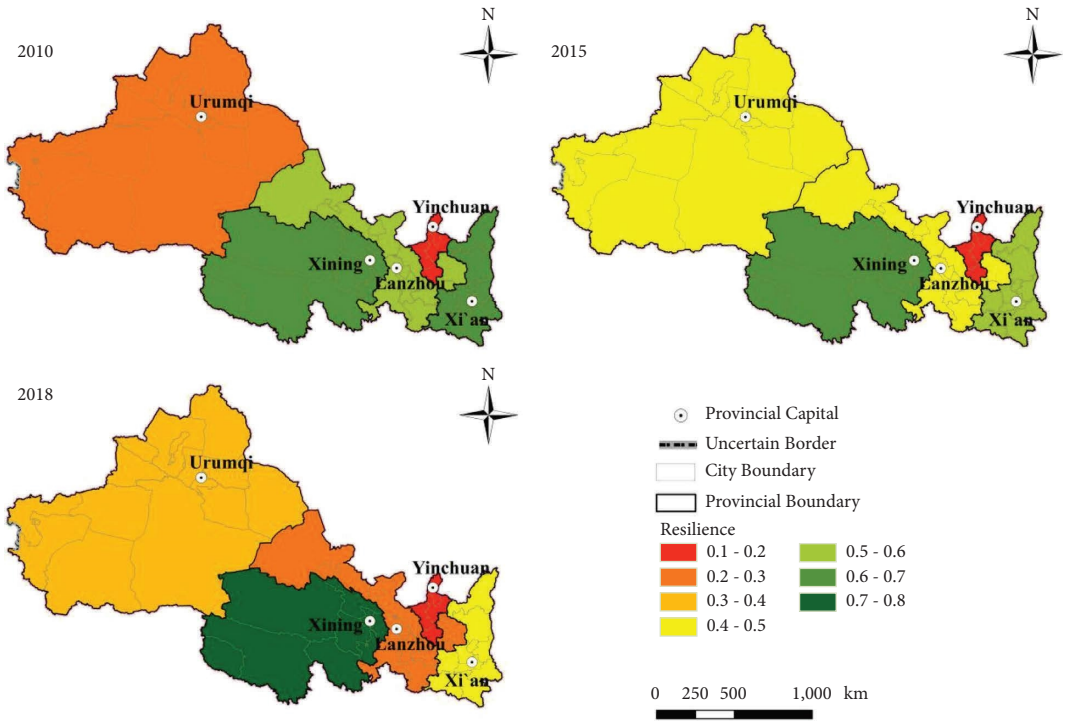

Figure 20: Spatial distribution pattern of provincial resilience.

organization increased greatly, and learning adaptability and transformability showed an upward trend, indicating that it was in the reorganization-exploitation stage (α-r). Yinchuan city, the capital of the province, has a high urbanization rate and a small gap between urban and rural areas. As the central city of the urban agglomeration along the Yellow River, it has received a good development opportunity and also drives the high-quality development of the whole autonomous region. The resilience index of Gansu Province continues to decline, the decline is large, stability first increases and then decreases, the self-organization change is small, and learning adaptability and transformability decrease slightly, indicating that it is in the conservation-release stage (K-Ω). The development of Gansu Province has entered a bottleneck period, the solidification of resources is obvious, and urban development is restricted. The cities under its jurisdiction are based on industry and agriculture, and the industrial structure is stable, so urban transformation is slow. At the same time, the level of urban economic development in the province is low, but the population is highly concentrated, resulting in unbalanced resource distribution, serious loss of high-tech talents and industries, low learning and adaptation ability and transformation ability of the region, and lack of potential development power. The resilience index of Qinghai Province is high and rising slowly, stability is basically unchanged, self-organization is high and increases significantly, and learning adaptability and transformation are slightly reduced, indicating that it is in the exploitation-conservation stage (r-K). The development of the province is on the rise, with good resource endowment, and the industrial structure has begun to transform. However, due to the low level of industrial sophistication after transformation, the economic growth effect of industrial development has not been fully shown, and the income gap between urban and rural residents is widening, resulting in the imbalance between urban and rural development. The resilience index of Xinjiang Autonomous Region increased first and then decreased and fluctuated greatly, stability continued to decline, self-organization was low, and learning adaptability and transformability increased to varying degrees, indicating that it was in the stage of development reorganization (α). The development model of the province is complex, the agglomeration effect is weak, and urban development faces many disturbances due to the unreasonable economic development layout, lagging infrastructure construction and environmental conditions. It can be seen that when the development power is abundant, the adaptive cycle stage of the province is the same as the average level of all cities in the region and that when the power is insufficient and urban problems are obvious, the province will move backward the average level of all cities in the region as the adaptive cycle stage.

5. Discussion

5.1. Scale Heterogeneity of Urban and Regional Resilience. Due to the differences in the social economic environment, the leading forces promoting regional development, and the operating mechanism, regions of different scales often have differences in their ability to resist and recover when facing external shocks. In this paper, through the comparison of resilience between cities and regions, it is found that the resilience index is significantly different at different scales,

Table 2: Adaptive cycle classification of cities in five provinces of northwest China.

Stages	City	Characteristic
Rapid exploitation (r)	Weinan, Hanzhong, Shangluo, Guyuan, Haidong, and Haibei	The urban resilience index increased rapidly, the stability of system structure improved, and materials, energy, and information poured in rapidly
Exploitation-conservation (r-K)	Lanzhou, Baiyin, Wuwei, Zhangye, Tianshui, Jiuquan, Xining, Huangnan, Guoluo, Hami, and Turpan	The increasing speed of the urban resilience index decreases, development tends to solidify, and the changes of various attributes are gentle
Stable conservation (K)	Xi'an, Tongchuan, Xianyang, Yan'an, Yulin, Yinchuan, Jiayuguan, Jinchang, Qingyang, Linxia, Haixi, Karamay, Changji, Boltala, and Hetian	The urban resilience index is basically stable or even shows a downward trend, the self-organization ability is small, the stability of the system structure is not easy to break, and it is urgent to improve the capacity of urban transformation and upgrading
Conservation-release (K-Ω)	Hainan, Urumqi, Shihezi, Tacheng, Altay, Yili, Bayinguoleng, Aksu, Kizilsu, and Kashgar	The urban resilience index continues to decline, stability is insufficient, urban development is disturbed, and urban problems appear. At this time, self-organization, learning adaptability, and transformability begin to improve and come into play, trying to solve problems and get rid of weakness
Development reorganization (α)	Pingliang, Dingxi, and Longnan	The urban resilience index rises, one or several characteristic attribute values change significantly, and the city begins to replan the development route and prepare to enter a higher level of the adaptive cycle
Reorganization -exploitation (α-r)	Baoji, Ankang, Gannan, Yushu, Wuzhong, Zhongwei, and Shizuishan	The urban resilience index rebounded greatly, the system stability gradually improved, the accepted entropy began to increase rapidly, and the city has transitioned to a higher-level adaptive cycle

which is consistent with the widely held views of scholars [55, 56].

At the same time, this study points out that, at the city scale, the resilience of the five provincial capitals is in the leading position among the 52 cities, at the urban agglomeration scale, the resilience index of Guanzhong Plain urban agglomeration is higher than that of other urban agglomerations in the study area, and at the provincial scale, Qinghai Province is the region with the highest resilience among the five provinces in northwest China. These research results can be verified by similar studies of other scholars. Such as Lu et al. [57] conducted an empirical study on resilience of 31 provincial capital cities in China. They found that provincial capital cities have agglomeration effects and are significantly affected by their own geographical locations, development conditions, and national policies. Therefore, they have strong adaptability when facing external shocks and can quickly recover in a short period. Fang [58] found that the development orientation of each urban agglomeration in the Yellow River basin of China is different. Among them, Guanzhong Plain urban agglomeration is the strategic pivot of the country's opening to the west and an important growth pole leading the development of the northwest region. Therefore, improving the resilience of urban agglomeration, resisting shocks and achieving adaptive development are effective measures for the sustainable development of the region. Yang [59] pointed out in the comparison of the economic development status of 31 provinces in China that, in the great opportunity of the Western Development Strategy, Qinghai Province, relying on its superior resource conditions, is likely to surpass some traditional development stages and achieve local leapfrog development.

5.2. Scale Heterogeneity of Urban and Regional Adaptive Cycles. Due to different socioeconomic status and development potential, different cities and regions are in different adaptive cycle stages. The research results of this paper show that all cities or regions in the study area have great differences in their system characteristics and resilience levels, resulting in inconsistent stages of their adaptive cycles and development levels, which is consistent with the views of previous scholars [16, 60]. Some of them have stable urban development structure and coordinated development of various elements of the system, while others have rigid urban development models, and urban problems are gradually emerging. The polarization phenomenon shown in the research results is similar to that of Li et al. [61], who also pointed out that there are two half cycles of growth and weakness in the regional economic system. The reason is that the higher the urban resilience, the stronger the system's ability to absorb and transform shocks, and the adaptive cycle will be in a benign state; otherwise, it will be in a vicious circle.

The results also show that the adaptive cycle stage of urban agglomerations is consistent with its core region when the scale changes. The research by Fang et al. [62] and Ye et al. [63] can confirm this result from the side. They pointed out that core cities play a leading role in economic development, social structure, strategic policies, and other aspects and are important growth poles leading the development of urban agglomeration. In assessing the high-quality development of urban agglomerations in the Yellow River basin of China, Ma and Xu [64] also pointed out that urban agglomerations should strengthen the radiating and driving effect of core cities on the overall urban agglomeration so as to promote the high-quality development of the entire Yellow River basin through the impact of the overall high-quality development of urban agglomerations.

In addition, when this study transforms from an urban scale to a provincial scale, it is found that the development stage of the provincial adaptive cycle is related to the average level of all cities in the region. Li [65] also conducted a similar study for the five provinces in northwest China. He found in the analysis of multifactor urban network structure that the development levels of cities in the region were significantly different and that the provinces with multiple high-level cities within their jurisdiction had a higher development level of comprehensive quality than other provinces, and vice versa. For example, when Lei [66] studied the coordinated development of cities and environment in central China at different scales, he found that when the spatial agglomeration phenomenon of well-coordinated regions at the urban scale is displayed at the provincial scale, provinces where the agglomeration phenomenon occurs also have the characteristics of good coordination between cities and environment. Therefore, regions at different scales need to pay attention to their own development and the construction of adaptive capacity.

6. Conclusion

As the direct subject of dealing with uncertain risks, it is of great importance to build resilient cities with the ability of resisting, dispelling, and adapting to uncertain risks to mitigate risk impacts and promote urban security and sustainable development. Based on the adaptive cycle model, this paper analyzed the spatial and temporal characteristics and adaptive cycle of the resilience of cities, urban agglomerations, and provinces in northwest China from 2010 to 2018. The results show that the resilience level of cities in the five provinces of northwest China is on the rise, and the differences between cities are gradually narrowing. At the same time, the spatial distribution characteristics of urban resilience are "one super and many strong, high in the east, and low in the west." The number of cities in the stable conservation stage is the largest, followed by the number of cities in the exploitation-conservation stage and conservation-release stage, and the number of cities in the development reorganization stage is the least. Second, the resilience of urban agglomerations varies greatly, showing a spatial distribution characteristic of "high in the southeast and low in the northwest." It is worth noting that the development stage of the adaptive cycle of each urban agglomeration is different, but it is consistent with its central urban area. Finally, the level of resilience varies greatly among provinces, and the development stage of the adaptive

cycle is similar to the average level of all cities in the region and is closely related to their respective development forces and urban problems.

Based on the above research results, the five provinces in northwest China should strengthen the awareness of the challenges and disturbances faced by cities and regions and pay attention to the building of resilience. Second, we should always accurately locate the development stage of the adaptive cycle and carry out targeted economic and social adjustment and transformation development. It is worth noting that, for cities in the rising period or gradually locked in the development path, when there are many interferences such as national policies, traffic construction, population aging, too fast population agglomeration, and environmental restrictions, we should give full play to urban transformation ability, accurately foresee problems, avoid the negative impact of interference to the largest extent through advanced structural reform, and seize the opportunity to achieve a higher level of development. For cities with urban problems, the main goal is to promote urban transformation and eliminate urban problems by improving the learning and innovation ability of the government, enterprises, and individuals and using innovative thinking to put forward new development ideas that can adapt to changes while improving infrastructure construction. Finally, for cities in other stages, the focus should be on strengthening the unity and coordination of the social system, economic system, and environmental system. While improving basic social services and increasing investment in production and construction, we should pay attention to protecting the environment and consolidating the stability of the system structure so as to improve urban resilience and achieve sustainable development.

Data Availability

The social and economic statistics are from the China provincial statistical yearbook, China urban statistical yearbook, and the statistical bulletin of national economic and social development of some cities. Land use-type data and vegetation index data are from the data center of resources and environment science, Chinese Academy of Sciences (https://www.resdc.cn). DEM data come from geospatial data cloud (https://www.gscloud.cn/) with a resolution of 1 km.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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References

[1] K. Borsekova, P. Nijkamp, and P. Guevara, "Urban resilience patterns after an external shock: an exploratory study," *International Journal of Disaster Risk Reduction*, vol. 31, pp. 381–392, 2018.

[2] T. P. Hughes, A. H. Baird, D. R. Bellwood et al., "Climate change, human impacts, and the resilience of coral reefs," *Science*, vol. 301, no. 5635, pp. 929–933, 2003.

[3] Y. Zheng and C. Z. Lin, "Theoretical basis and assessment methods of resilient cities," *City*, vol. 6, pp. 22–28, 2017.

[4] Resilience Alliance, *Urban Resilience Research Prospectus*, CSIRO, Canberra, Australia, 2007.

[5] T. M. P. Nguyen, K. Davidson, and B. Gleeson, "Metropolitan strategies and climate governance: towards new evaluative approaches: metropolitan strategies and climate governance," *International Journal of Urban and Regional Research*, vol. 42, no. 5, pp. 934–951, 2018.

[6] B. Gleeson, T. Darbas, and S. Lawson, "Governance, sustainability and recent Australian metropolitan strategies: a socio-theoretic analysis," *Urban Policy and Research*, vol. 22, no. 4, pp. 345–366, 2004.

[7] T. Y. Li, P. Y. Niu, and C. L. Gu, "A review of the research framework of resilient cities," *Urban Planning Forum*, vol. 5, pp. 23–30, 2014.

[8] C. L. Xiu, Y. Wei, and Q. Wang, "Evaluation of urban resilience of Dalian city based on the perspective of "Size-Density-Morphology"," *Acta Geographica Sinica*, vol. 73, no. 12, pp. 51–64, 2018.

[9] SunY, L. C. Zhang, and S. M. Yao, "Evaluating resilience of prefecture cities in the Yangtze River delta region from a socio-ecological perspective," *China population, resources and environment*, vol. 27, no. 8, pp. 151–158, 2017.

[10] R. Q. Li, H. Huang, and R. Zhou, "Resilience curve modelling of urban safety resilience," *Journal of Tsinghua University*, vol. 60, no. 1, pp. 1–8, 2020.

[11] P. Cui and D. Li, "A SNA-based methodology for measuring the community resilience from the perspective of social capitals: take Nanjing, China as an example," *Sustainable Cities and Society*, vol. 53, Article ID 101880, 2020.

[12] Y. Zhang, H. Long, and L. Ma, "How does the community resilience of urban village response to the government-led redevelopment? A case study of Tangjialing village in Beijing," *Cities*, vol. 95, 2019.

[13] M. Roy, "Planning for sustainable urbanisation in fast growing cities: mitigation and adaptation issues addressed in Dhaka, Bangladesh," *Habitat International*, vol. 33, no. 3, pp. 276–286, 2009.

[14] B. Muller, "Mending man's ways: wickedness, complexity and off-road travel," *Landscape and Urban Planning*, vol. 154, pp. 93–101, 2016.

[15] Y. C. Chiang, "Exploring community risk perceptions of climate change—a case study of a flood-prone urban area of Taiwan," *Cities*, vol. 74, pp. 42–51, 2018.

[16] Y. Zheng, K. Wang, Y. Wu et al., "Classification and evaluation of resilient cities based on adaptive cycle: a case study of sponge cities and climate-resilient cities in China," *Cancer Letters*, vol. 431, no. 3, pp. 31–42, 2018.

[17] D. P. González, M. Monsalve, R. Moris, and C. Herrera, "Risk and resilience monitor: development of multiscale and multilevel indicators for disaster risk management for the communes and urban areas of Chile," *Applied Geography*, vol. 94, no. 5, pp. 262–271, 2018.

[18] K. Samuelsson, M. Giusti, G. D. Peterson, A. Legeby, S. A. Brandt, and S. Barthel, "Impact of environment on people's everyday experiences in Stockholm," *Landscape and Urban Planning*, vol. 171, pp. 7–17, 2018.

[19] N. McClintock, D. Mahmoudi, M. Simpson, and J. P. Santos, "Socio-spatial differentiation in the sustainable City: a mixed methods assessment of residential gardens in metropolitan Portland, Oregon, USA," *Landscape and Urban Planning*, vol. 148, pp. 1–16, 2016.

[20] M. L. Marsal-Llacuna and M. E. Segal, "The intelligenter method (I) for making "smarter" city projects and plans," *Cities*, vol. 55, no. 6, pp. 127–138, 2016.

[21] N. Aoki, "Adaptive governance for resilience in the wake of the 2011 great east Japan earthquake and tsunami," *Habitat International*, vol. 52, no. 3, pp. 20–25, 2016.

[22] S. Bouzarovski, J. Salukvadze, and M. Gentile, "A socially resilient urban transition? The contested landscapes of apartment building extensions in two post-communist cities," *Urban Studies*, vol. 48, no. 13, pp. 2689–2714, 2011.

[23] C. Peng, Y. Z. Lin, and C. L. Gu, "Evaluation and optimization strategy of city network structural resilience in the middle reaches of Yangtze River," *Geographical Research*, vol. 37, no. 6, pp. 1193–1207, 2018.

[24] S. M. Wei and J. H. Pan, "Network structure resilience of cities at the prefecture level and above in China," *Acta Geographica Sinica*, vol. 76, no. 6, p. 14, 2021.

[25] X. J. Yang, Y. Z. Shi, and Z. Q. Wang, "Impact of road construction on social-ecological system in Qinling Mountains: a perspective of community resilience," *Acta Geographica Sinica*, vol. 70, no. 8, pp. 1313–1326, 2015.

[26] B. Zheng, Y. H. Hao, and N. Ning, "Community resilience to disaster risk in Sichuan province of China:an analysis of TOPSIS," *Chinese Journal of Public Health*, vol. 33, no. 5, pp. 699–702, 2017.

[27] The Rockefeller Foundation, "100 resilient cities," 2018, https://www.rockefellerfoundation.org/our-work/initiatives/100-resilient-cities/,%202018-03-02.

[28] Y. Li, M. Kappas, and Y. F. Li, "Exploring the coastal urban resilience and transformation of coupled human-environment systems," *Journal of Cleaner Production*, vol. 195, no. 10, pp. 1505–1511, 2018.

[29] C. Eken and R. Alpar Atun, "The self-organizing city and the architecture of metabolism: an architectural critique on urban growth and reorganization," *Sustainability*, vol. 11, no. 19, p. 5326, 2019.

[30] B. D. Fath, C. A. Dean, and H. Katzmair, "Navigating the adaptive cycle: an approach to managing the resilience of social systems," *Ecology and Society*, vol. 20, no. 2, p. 24, 2015.

[31] C. Wilkinson, "Social-ecological resilience: insights and issues for planning theory," *Planning Theory*, vol. 11, pp. 148–169, 2011.

[32] L. H. Gunderson and C. S. Holling, *Panarchy: Understanding Transformations in Human and Natural Systems*, Island Press, Washington, DC, USA, 2001.

[33] B. Walker and D. Salt, *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*, Island Press, Washington, DC, USA, 2006.

[34] H. Hung, C. Yang, C. Chien, and Y. C. Liu, "Building resilience: mainstreaming community participation into integrated assessment of resilience to climatic hazards in metropolitan land use management," *Land Use Policy*, vol. 50, pp. 48–58, 2016.

[35] B. Walker, C. S. Holling, S. R. Carpenter, and A. P. Kinzig, "Resilience, adaptability and transformability in social-ecological systems," *Ecology and Society*, vol. 9, no. 2, pp. 5–3447, 2004.

[36] C. Folke, S. R. Carpenter, B. Walker, M. Scheffer, T. Chapin, and J. Rockström, "Resilience thinking: integrating resilience, adaptability and transformability," *Ecology and Society*, vol. 15, no. 4, p. 20, 2010.

[37] D. Fang, Z. Li, and N. Li, "Urban resilience: a perspective of system of systems in trio spaces," *China Civil Engineering Journal*, vol. 50, no. 7, pp. 1–7, 2017.

[38] A. B. Wildavsky, *Searching for Safety*, vol. 10, Transaction Publishers, Piscataway, NJ, USA, 1988.

[39] P. Lu and D. Stead, "Understanding the notion of resilience in spatial planning: a case study of Rotterdam, The Netherlands," *Cities*, vol. 35, pp. 200–212, 2013.

[40] S. Woolf, J. Twigg, P. Parikh, A. Karaoglou, and T. Cheaib, "Towards measurable resilience: a novel framework tool for the assessment of resilience levels in slums," *International Journal of Disaster Risk Reduction*, vol. 19, pp. 280–302, 2016.

[41] D. Brand and H. Nicholson, "Public space and recovery: learning from post-earthquake Christchurch," *Journal of Urban Design*, vol. 21, no. 2, pp. 159–176, 2016.

[42] B. H. Wu and A. Chen, "Framework of the evaluation model resilient cities," *Science and Technology Review*, vol. 36, no. 16, pp. 94–99, 2018.

[43] Y. P. Liu, H. F. Wang, and H. W. Qian, "Urban resilience: connotation and evaluation system," *Journal of Catastrophology*, vol. 34, no. 1, pp. 8–12, 2019.

[44] Y. Wu, W. Que, Y. G. Liu, L. Cao, S. Liu, and J. Zhang, "Is resilience capacity index of Chinese region performing well? Evidence from 26 provinces," *Ecological Indicators*, vol. 112, Article ID 106088, 2020.

[45] Q. Zhou, M. Zhu, Y. Qiao, X. Zhang, and J. Chen, "Achieving resilience through smart cities? Evidence from China," *Habitat International*, vol. 111, Article ID 102348, 2021.

[46] J. H. Zhu and H. X. Sun, "Research on spatial-temporal evolution and influencing factors of urban resilience of China`s three metropolitan agglomerations," *Soft Science*, vol. 34, pp. 72–79, 2020.

[47] X. Liu, B. Derudder, and K. Wu, "Measuring polycentric urban development in China: an intercity transportation network perspective," *Regional Studies*, vol. 50, no. 8, pp. 1302–1315, 2016.

[48] Y. F. Qin and J. K. Guo, "Network spatial connection of coastal port city system from the perspective of multiple flows. Sci. Geogr. Sin," 2022, http://kns.cnki.net/kcms/detail/22.1124.P.20221008.1405.006.html.

[49] B. Wang, *The Research of Indicators Construction and Evaluation of Learning City—Based on the Perspective of Generalized Education Innovation Performance*, Dongbei University of Finance and Economics, Dalian, China, 2013.

[50] M. L. Moore, P. Olsson, W. Nilsson, L. Rose, and F. R. Westley, "Navigating emergence and system reflexivity as key transformative capacities: experiences from a Global Fellowship program," *Ecology and Society*, vol. 23, no. 2, p. 38, 2018.

[51] X. H. Feng, J. Lei, C. L. Xiu, J. Li, L. Bai, and Y. Zhong, "Analysis of spatial scale effect on urban resilience: a case study of shenyang, China," *Chinese Geographical Science*, vol. 30, no. 6, pp. 1005–1021, 2020.

[52] M. Xu, X. Zhu, and J. Z. Li, "Evaluation of land ecological security in hunan province based on DPSIR-TOPSIS model," *Journal of Glaciology and Geocryology*, vol. 34, no. 5, pp. 1265–1272, 2012.

[53] Q. Li, A. G. Schissler, V. Gardeux et al., "N-of-1-pathways MixEnrich: advancing precision medicine via single-subject analysis in discovering dynamic changes of transcriptomes: a case study of Xuzhou city," *BMC Medical Genomics*, vol. 10, no. 1, pp. 27–32, 2017.

[54] J. Simmie and R. Martin, "The economic resilience of regions: towards an evolutionary approach," *Cambridge Journal of Regions, Economy and Society*, vol. 3, no. 1, pp. 27–43, 2010.
[55] A. Brown, A. Dayal, and C. Rumbaitis Del Rio, "From practice to theory: emerging lessons from Asia for building urban climate change resilience," *Environment and Urbanization*, vol. 24, no. 2, pp. 531–556, 2012.
[56] A. E. Quinlan, M. Berbés-Blázquez, L. J. Haider, and G. D. Peterson, "Measuring and assessing resilience: broadening understanding through multiple disciplinary perspectives," *Journal of Applied Ecology*, vol. 53, no. 3, pp. 677–687, 2016.
[57] L. Lu, H. W. Zhou, and Q. Q. Xu, "Comprehensive evaluation and application of urban resilience from the perspective of multidimensional association network," *Urban Problems*, vol. 8, pp. 42–55, 2020.
[58] C. L. Fang, "Spatial organization pattern and high-quality development of urban agglomeration in the Yellow River basin," *Economic Geography*, vol. 40, no. 6, pp. 1–8, 2020.
[59] Y. Yang, *Research on Comprehensive Evaluation of New Urbanization Level in Henan Province*, Zhengzhou University, Zhengzhou, China, 2019.
[60] F. H. Luo, Y. X. Liu, J. Peng, and J. Wu, "Assessing urban landscape ecological risk through an adaptive cycle framework," *Landscape and Urban Planning*, vol. 180, pp. 125–134, 2018.
[61] L. G. Li, P. Y. Zhang, and J. T. Tan, "Review on the evolution of resilience concept and research progress on regional economic resilience," *Human Geography*, vol. 2, pp. 1–7, 2019.
[62] C. L. Fang, Z. B. Wang, and H. T. Ma, "The theoretical cognition of the development law of China's urban agglomeration and academic contribution," *Acta Geographica Sinica*, vol. 73, no. 4, pp. 651–665, 2018.
[63] S. S. Ye, M. M. Cao, and S. Hu, "Evolution of economic connection network structure in the Guanzhong Plain City Cluster and its impact on economic growth," *Arid Land Geography*, vol. 45, no. 1, pp. 277–286, 2022.
[64] H. T. Ma and X. F. Xu, "High-quality development assessment and spatial heterogeneity of urban agglomeration in the Yellow River basin," *Economic Geography*, vol. 40, no. 4, pp. 11–18, 2020.
[65] X. Y. Li, *Study on Urban Spatial Network Structure in Northwest China*, Lanzhou university, Lanzhou, China, 2020.
[66] L. T. Lei, *Research on the Space-Time Differentiation Pattern of Coordinated Development of New-Urbanization and Eco-Environment in central China at Different Scale*, Henan university, Henan, China, 2018.