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Evaluation of disaster resilience and diagnosis of obstacles in rural areas of southern Xinjiang, China, based on the PSR model

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Abstract

Purpose – This study aims to explore the disaster resilience level (pre-disaster defense pressure, emergency state in disaster, post-disaster recovery response) and the obstacle factors of resilience improvement in rural areas of southern Xinjiang under the influence of meteorological disasters.

Design/methodology/approach – A cross-sectional household survey was used. Structured interviews and questionnaires were conducted in representative villages of eight counties and cities in southern Xinjiang. This study used both descriptive statistics and an econometric model. The model was used to calculate the disaster resilience level in the study area. The numerical grade and obstacle degree of resilience were characterized by SPSS software.

Findings – The model results confirmed the "gradient-like" distribution feature of lower resilience in the east and south and higher resilience in the west and north. Areas of high rural disaster resilience mainly concentrate in Kashgar on the western edge of the Taklimakan Desert and Korla in the north, whereas low-value areas are mainly distributed in Minfeng County–Ruoqiang County in the east of the desert. From each subsystem of the evaluation system, the obstacle degree of the rural disaster resilience level in southern Xinjiang is as follows: pre-disaster defense pressure > emergency state in disaster > post-disaster recovery response.

Originality/value – This study can calculate the relatively accurate value of rural resilience level by constructing pressure-state-response disaster response model, and then can provide directional and quantitative reference for the subsequent safety construction of different types of villages with resilience status.

Keywords Disaster resilience, PSR evaluation model, Southern Xinjiang, Obstacle degree diagnosis, Rural area

Paper type Research paper

1. Introduction

Under the continuous influence of global climate change and human activities, natural disasters have become more frequent and serious. In 2023 alone, the economic losses caused by natural disasters worldwide reached $280bn (Swiss Re Swiss Re Institute, 2024), and the prevention and treatment of global disasters have become an urgent task for the international

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community. The World Meteorological Organization's "Report on the Climate Situation in Asia in 2023" recently noted that the long-term warming trend in Asia was accelerating, and the warming rate was higher than the global average. In 2023, Asia was the region most severely affected by extreme weather disasters worldwide. China is one of the countries that was most severely affected by natural disasters in Asia, experiencing a wide range of disaster types, broad geographical distribution, high frequency and substantial losses (Zhang and Zhou, 2019). According to the statistics of the China Emergency Management Department, in 2021, national meteorological disaster caused 11,739,000 hectares of crops, 867 people died or disappeared, and the direct economic loss was 334.02 billion yuan (China Meteorological Administration, 2022).

Due to the relatively weak basic disaster response facilities in rural areas, the disaster response problem is more serious. Due to the unique geographical location around the desert in southern Xinjiang, China, disasters have been a prominent issue since ancient times. According to historical records, there were disasters in southern Xinjiang almost every year and some years had multiple disasters. Thus, many cities and counties in southern Xinjiang have taken large-scale resettlement measures to avoid disasters and benefit the people, but these measures have also caused a series of problems. For example, residents must abandon local traditional industries, the original ecological disaster-prevention environment has not been maintained, residential buildings in new villages lack regional characteristics, the relationship among native geographical organizations is broken, immigrants cannot effectively integrate into their new homes, and the sense of belonging to a home is lost. Therefore, it is urgent to correctly evaluate the rural disaster resilience and discover the main obstacle factors that affect the improvement of rural disaster resilience using an obstacle factor diagnosis model according to the evaluation results. At present, there are relatively few researches on disaster resilience in rural areas and even fewer studies on the quantitative evaluation of disaster resilience in southern Xinjiang. There are many existing institutional frameworks for evaluation, among which the Organization for Economic Co-operation and Development has proposed the pressure-state-response (PSR) model, which has a strong connection with the idea of disaster resilience in studying the basic core of residential environment and has a strong correlation with the mechanism of resilience. Therefore, in this study, for the first time, we systematically established a quantitative evaluation system of rural resilience in southern Xinjiang from the interdisciplinary perspective of economics, management, architecture and ecology, which filled the gap in the field of rural disaster resilience evaluation in southern Xinjiang, China, and helped to improve rural resilience to disasters and reduce disaster losses.

The purpose of this work is to clarify the complex and urgent disaster safety construction of rural settlements in southern Xinjiang by introducing the concept of resilience theory and integrating it into the perspective of interdisciplinary research with its connotation of "dynamic recovery and adaptation." The characteristics of disaster types faced by rural settlements in southern Xinjiang are selected and combined with expert evaluation, field survey and questionnaire interviews to construct the evaluation index system of a PSR disaster response model (pre-disaster defense pressure, emergency state in disaster and post-disaster recovery response). Then, according to the results of the rural quantitative evaluation, suitable safety construction strategies for different types of resilient villages are introduced for future orientation and classification. This relatively more accurate strategy is expected to enhance the orientation of resilience, so that all regions or similar regions can be evaluated based on the present and enhance their resilience to different types and magnitudes of disasters.

2. Conceptual framework

The word "resilience" was originally derived from the Latin word "resillio," which means "to jump back to the original state" (Klein *et al.*, 2003). In 1990, resilience was first introduced into the field of urban planning as a term, which first appeared in the study of urban disasters (Takewaki, 2013). Traditional disaster reduction planning mainly focuses on the disaster risks that the physical environment can bear, such as buildings in earthquakes and drainage systems in floods. However, there is a limit to the physical environment's ability to bear the disaster intensity. Whether a city or a village can restore order and vitality after a disaster depends on how the populated groups and management can effectively cope with the disaster and rebuild after the disaster and calmly cope with the next disaster through empirical learning. Therefore, the resilience theory has been introduced into the disaster research of human settlement system (Jabareen, 2013).

The theory of resilience was first introduced into urban research from the perspective of urban disaster prevention, and the study of regional disaster resilience plays an important role in discussing the impact of climate change on human settlements. There are still many disputes about the basic concept of disaster resilience in academic circles, but a basic consensus is that disaster resilience is regarded as an inherent ability of a system, community or society, which can change its non-core attributes to rebuild itself after being affected by shocks or pressures, so as to adapt and survive (Manyena, 2006). In 2006, the United Nations International Strategy for Disaster Reduction (UNISDR) (2014) defined "resilience is the ability of a system, community or society to resist, absorb, adapt and recover from its impact in a timely and effective way when exposed to danger, including protecting and restoring its necessary infrastructure and functions." The limited expression of international organizations is of guiding significance for countries and regions to enhance their resilience thinking in cognitive crises and disasters.

Until now, considerable achievements have been made in the research on disaster resilience and its improvement abroad. As early as the Loma Prieta earthquake in 1989 and the Dongwan Mountain fire disaster in 1991, Berkeley proposed strategies such as strengthening town facilities, earthquake subsidies and free maintenance to improve the resilience level of the city in severe disaster environment (Chakos *et al.*, 2002). Tassar has specially set up rain and flood management facilities for frequent tornadoes and floods, established open public spaces on a large scale, unified drainage planning and other resilient measures, which greatly reduced the disasters caused by floods (Prieto, 2002). In recent years, for example, from the perspective of improving the buffering, absorption, recovery and adaptability of the settlement system, A.M. Aslam paid attention to the ability of the current situation of residential areas to handle risks and introduced an index system to evaluate the resilience of residential areas, which included architecture and landscape, public facilities and services, natural resources, economy and industry, residential management system, public welfare and welfare (Aslam Saja *et al.*, 2021). T.W. Haase put forward that the adaptive planning of open space can effectively improve the regional flood-fighting ability and reduce the impact of rain and flood, but only swamp wetlands and grasslands have played a role in disaster reduction, while agricultural land has not. On the premise of meeting the needs of land development, the impervious surface can be transformed into permeable surface, which can significantly improve the rain and flood resilience of the city (Haase *et al.*, 2021). T. Muhammad investigated and analyzed 90 countries from 1995 to 2019, hypothesized that resilience construction could obviously reduce disaster-related losses in developed countries and introduced that infrastructure, economic situation, public awareness, health habits, communication technology and effective institutions should be the main aspects of the rapid recovery of residential areas after disasters (Muhammad *et al.*, 2023). Taking Latin America and the Caribbean as an example, S. Lucatello believes that the National Bureau of

Statistics is an important tool to reduce regional disaster risks, including improving the resilience of local floods, landslides and droughts by integrating social, ecological, economic and governance resources (Lucatello and Irasema, 2024). Some international studies have put forward an indicator-based system to measure disaster resistance. For example, Kim *et al.* (2025) developed a resilience index for South Korea using BRIC framework data. Arik *et al.* (2026) proposed a framework to separate coping ability from adaptive ability. These studies have influenced our choice of PSR models and indicators.

The related research progress of resilience evaluation in China remains in the initial stage. This area has basically experienced the introduction of foreign resilience evaluation systems to the initial exploration of local regional resilience evaluation. Yang *et al.* (2016), Li (2017), Gu and Cao (2019), Peng *et al.* (2021) and Li *et al.* (2023) introduced the foreign research content on disaster resilience to China, including the concept and theoretical development of disaster resilience, alongside the basic strategies of disaster-prevention planning for resilient cities. Taking the practice of fighting Hurricane Katrina in New Orleans, USA, as an example, Wang and Wang (2018) summarized the experience of disaster resilience, which included the following steps: understanding disasters, formulating targeted coping strategies, joint deployment of relevant departments, actively introducing external rescue funds, increasing digital media publicity and clarifying the cultural orientation of urban disaster response. This process is worth learning from developing countries. Zhai *et al.* (2022) assessed the actual situation in China and selected the problems faced by disaster-prevention construction in today's resilient cities in China; the main problems are insufficient theoretical research, unclear understanding, weak awareness of residents regarding disaster risks and lack of guidance from relevant laws and regulations.

In summary, related research on resilience began earlier abroad than in China and has a notably mature framework system due to the extension of interdisciplinary integration. However, research on disaster resilience mostly focuses on specific disasters in local areas, and the diversity of regions makes it difficult for disaster prevention and control research with different types of regional backgrounds to have a universally suitable strategic reference value. Therefore, related research on disaster resilience in China must be analyzed and explored in combination with its regional characteristics. The climate in southern Xinjiang is extreme, and all types of disasters have frequently occurred since ancient times. Until now, there has been no research in this area of disaster resilience. There has been seismic analysis of residential structure systems in the civil structure discipline, whereas research on rural disaster resilience systems at the sociology and management level is relatively scarce. Therefore, it urgently needs of attention and analysis from relevant researchers from multiple perspectives.

In this study, we define disaster resilience as the ability of a rural system to resist, absorb, adapt to and recover from the effects of meteorological disasters in a timely and effective way. This definition follows the one given by the United Nations International Strategy for Disaster Reduction (UNISDR, 2014). We focus on three stages: before a disaster, during a disaster and after a disaster. These three stages match the PSR model. Pressure refers to the pre-disaster defense load. State refers to the emergency condition during the disaster. Response refers to the recovery actions taken after the disaster. By using this clear framework, we can measure resilience in a structured way and compare different rural areas.

3. Overview of cases

3.1 Study area

South Xinjiang, China, has a vast territory. The Tarim Basin is the main body; it is located between 73 and 93 east longitude and 35 and 43 north latitude and covers an area of approximately 1.36 million square kilometers, i.e. approximately 1/7 of the country's land

area. The central part of the basin is the Taklimakan Desert, which is the second-largest mobile desert in the world and is surrounded by inhabited oases (Figure 1). We evaluated the disaster resilience of typical traditional villages in 41 counties in 8 cities (including county-level cities), including Turpan, Hami, Kashgar, Hotan, Bayingol Mongolian Autonomous Prefecture, Aksu and Kizilsu Kirgiz Autonomous Prefecture. Among them, eight municipal cities only represent the urban area, whereas county-level cities represent all areas in the county (including towns and administrative villages). There are 6,015 administrative villages in southern Xinjiang.

There are disasters in southern Xinjiang almost every year, and some years have multiple disasters per year. According to previous statistics, the main types of disaster-causing factors in southern Xinjiang are high fever and drought, strong wind and dust, flood, cold wave, pests and diseases, hail, freezing injury, snowstorm, frost and earthquake. Among them, disasters caused by high fever and drought, strong winds and dust, floods and hail can account for more than 50% of the total disasters. Due to the unique mountain basin in southern Xinjiang, with desert geographical situation in the middle, high fever, drought, strong wind and dust, which are the main types of disasters, are common in southern Xinjiang, while the disaster threats such as floods and blizzards are concentrated in the counties of Kunlun Mountain, Tianshan Valley and the edge of the foothills, showing the characteristics of regional high incidence.

3.2 Data collection

Research data were obtained from the statistical yearbook of the research area, statistical bulletin of meteorological conditions, regional city and county chronicles and field research by the research team. The research team consisted of 14 people and conducted three rounds of field research. We used a cross-sectional household survey design. For each county or city,

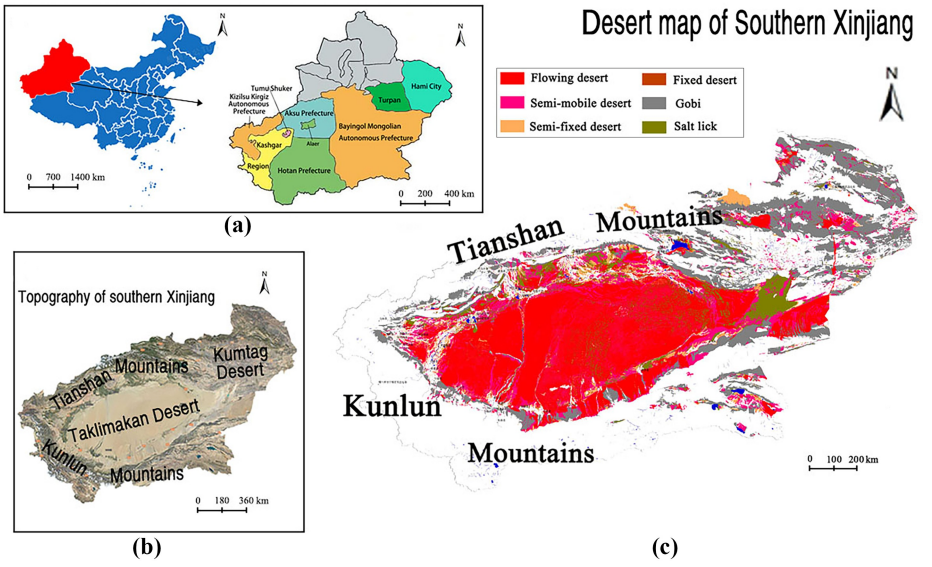


Figure 1. Study area. (a) Location indication of Xinjiang in China. (b) Location indication of southern Xinjiang. (c) Desert map of southern Xinjiang

we selected three villages as study units. These villages were randomly chosen from official lists of traditional villages. These lists were made by local governments at different levels, including autonomous region level, municipal level and county level. Villages on these lists are considered to have rich cultural and natural resources as well as historical, economic or social values. By using random selection from these lists, we aimed to get a representative sample of villages in southern Xinjiang. In total, we covered 49 counties and cities and 138 villages. Five questionnaires were collected from each village. The respondents included village leaders, disaster information officers, security officers, senior villagers and villagers who had taken part in disaster response or recovery work. We did not randomly pick ordinary villagers. This sampling method helped us collect reliable information on disaster resilience from people with direct knowledge.

In total, 690 questionnaires and face-to-face interview records were distributed in this study. A total of 685 questionnaires were collected, of which 672 were valid and the effective questionnaire rate was approximately 98%. Most of the data required for the study were obtained through the team questionnaire, some of which could be obtained by investigators directly surveying or observing, and others could be obtained by calculating the original data.

4. Methodology

4.1 Model application

The PSR model was first established by Canadian statisticians J. David and M. Anthony in 1979 and further developed by the United Nations Environment Program to study environmental and ecological problems. In the PSR model system, the pressure (P) index refers to natural or human factors that exert pressure on the eco-social system and reflects the load caused by human and natural interference on the system. The state (S) index is the current state of a social ecosystem and represents the health state of the system. The response (R) index is the corresponding measures taken when the system faces risk pressure. PSR has become common in the evaluation of safety levels of ecological environment systems (Fu *et al.*, 2017).

Based on the logical correlation between the rural disaster resilience system and the PSR model, this work considers the countryside as a type of social and ecological complex system. Based on this understanding, the pressure, state and response can correspond to the pre-disaster defense pressure, rescue state in the disaster and post-disaster recovery response in rural areas, respectively. With the PSR model of rural disasters, “pre-disaster defense pressure” means the risk of disaster triggering and the possibility of adverse impact. The “emergency state in disaster” is the state and change of rural areas to resist the impact of disasters. “Post-disaster recovery response” refers to the experience and learning ability that form after the rural disaster crisis or long-term adaptation to disasters. Therefore, this work will construct a disaster resilience evaluation system for rural areas in southern Xinjiang based on the PSR model.

4.2 Index system construction

The 36 indicators in Table 1 were built through three steps. First, we reviewed existing studies on disaster resilience and the PSR model. Second, we considered the local characteristics of southern Xinjiang, including its desert environment, frequent meteorological disasters and rural living conditions. Third, we held discussions with experts in rural planning, disaster management and ecology. We also used feedback from our field visits and household surveys. Based on the principles of being systematic, scientific and practical, we selected indicators that could be measured using survey questions or local records. Each indicator was then assigned a direction, meaning whether a higher value is

Table 1. Evaluation index system of rural disaster resilience in southern Xinjiang

Target layer	System layer	Index layer	Factor layer	Index attribute	Weight value	Data source
Evaluation of rural disaster resilience	Pre-disaster defense pressure (P)	Ecological construction (P1)	(C1) Land desertification rate	–	0.0326	Statistical / spatial
			(C2) Sanitation	+	0.0064	Observation
			(C3) Ecological protection	+	0.0146	Questionnaire
		Risk investigation (P2)	(C4) Major disaster frequency	–	0.0057	Statistical
			(C5) Building vacancy rate	–	0.0128	Observation + questionnaire
			(C6) Degree of building integrity	+	0.0184	Observation
			(C7) Peripheral hidden danger source	–	0.0417	Observation
		Contingency reserve (P3)	(C8) Emergency drill	+	0.0235	Questionnaire
			(C9) Material reserves	+	0.0402	Observation + questionnaire
			(C10) Disaster-prevention planning	+	0.0783	Questionnaire
			(C11) Disaster propaganda	+	0.0094	Questionnaire
		Mass consciousness (P4)	(C12) Disaster common sense	+	0.0175	Questionnaire
			(C13) Vigilance consciousness	+	0.0062	Questionnaire
			(C14) Protection consciousness of ancient buildings	+	0.0017	Questionnaire
		Disaster-prevention facilities (P5)	(C15) Emergency shelter	+	0.1207	Observation
			(C16) Escape passway	+	0.0584	Observation
			(C17) Disaster-prevention infrastructure	+	0.0246	Observation
	Emergency state in disaster (S)	Emergency warning (S1)	(C18) Monitoring and early warning	+	0.0389	Questionnaire
			(C19) Contingency plan	+	0.0188	Questionnaire
		Mechanism coordination (S2)	(C20) Communication in surrounding villages	+	0.0113	Questionnaire
			(C21) Department coordination degree	+	0.0237	Questionnaire

(*continued*)

Table 1. Continued

Target layer	System layer	Index layer	Factor layer	Index attribute	Weight value	Data source
		Emergency disposal (S3)	(C22) Emergency response efficiency	+	0.0081	Questionnaire
			(C23) Temporary convener	+	0.0053	Questionnaire
			(C24) Mass safety transfer time	+	0.0048	Questionnaire
		Neighborhood mutual assistance (S4)	(C25) Neighborhood	+	0.0047	Questionnaire
			(C26) Disaster relief	+	0.0105	Questionnaire
		Transportation (S5)	(C27) Popularization of water source points	+	0.0112	Observation + questionnaire
			(C28) Distance from the city	+	0.0407	Statistical/spatial
	Disaster recovery response (R)	Guarantee welfare (R1)	(C29) Social insurance ratio	+	0.0264	Statistical
			(C30) Commercial insurance ratio	+	0.0093	Statistical
		Economic base (R^2)	(C31) Financial support	+	0.1482	Statistical + questionnaire
			(C32) Village collective income	+	0.0284	Statistical
			(C33) Family income	+	0.0462	Questionnaire
		Manpower security (R3)	(C34) Proportion of aging population	–	0.0093	Statistical
			(C35) Percentage of young- and middle-aged population	+	0.0291	Statistical
			(C36) Inhabitant	+	0.0124	Questionnaire

good (positive) or bad (negative). For example, land desertification rate is negative, while ecological protection is positive.

To make the evaluation process more transparent, we classified the data sources of the 36 indicators into four types. The first type is questionnaire based data. These indicators were measured by asking respondents to rate certain conditions or behaviors using a five point Likert scale. Examples include disaster common sense (C12), vigilance consciousness (C13) and emergency drill frequency (C8). The second type is observation based data. Our research team directly observed and recorded these indicators during village visits, such as building integrity (C6), peripheral hidden danger sources (C7) and escape passway condition (C16). The third type is statistical or spatial data. These indicators were obtained from local statistical yearbooks, meteorological bulletins or remote sensing images. Examples include land desertification rate (C1), major disaster frequency (C4) and proportion of aging population (C34). The fourth type is a combination of two or more sources. For example, building vacancy rate (C5) was checked by observation and also confirmed by talking with village leaders. Financial support (C31) was collected from village records and cross checked with questionnaire answers from village cadres. This classification is shown in the last column of Table 1. By separating the data sources, we hope to improve the reliability and reproducibility of our resilience evaluation.

4.3 Consideration of exposure in resilience index

The PSR model does not directly include exposure as a separate part. However, exposure still plays an important role in measuring disaster resilience. In our study, exposure is reflected through several indicators across the three subsystems. For example, in the pre-disaster defense pressure part, some indicators show the level of exposure of local people, buildings and infrastructure to weather related hazards. These indicators include land desertification rate (C1), major disaster frequency (C4) and peripheral hidden danger sources (C7). Also, building vacancy rate (C5) and degree of building integrity (C6) show how much the physical structures are exposed to risks. In the emergency state part, monitoring and early warning (C18) and mass safety transfer time (C24) indicate the exposure of communities when a disaster happens. In the post-disaster recovery part, the proportion of aging population (C34) and the percentage of young- and middle-aged people (C35) reflect demographic exposure. This kind of exposure affects how well a community can recover from a disaster. Therefore, even though exposure is not treated as an independent dimension in our index, it is already included in the pressure and state parts of the PSR framework. This helps us measure disaster resilience in rural southern Xinjiang in a more complete way.

4.4 Determination of index weight

The weight calculation of the index level was obtained using the entropy method according to the questionnaire survey results of the factor level. The entropy method was used for objective weighting and the index weight of the evaluation system was determined according to the principle that greater information entropy corresponds to smaller uncertainty, which can provide a scientific basis to evaluate the rural disaster resilience in southern Xinjiang scientifically and accurately. Due to the subjective factors of the respondents, it is difficult to make specific numerical distinctions between the measurement of various indicators through the degree of difference. Therefore, the survey questionnaire uses the five-level Likert scale when describing the degree of grade, that is, the following data of Grades 1–5 are the explanations of the scoring contents of some indicators in the questionnaire.

C1 Land desertification rate: Evaluate the degree of desertification of rural land year by year. According to the questionnaire, the area of land desertification increased to 1 point, increased to 3 points, almost remained unchanged at 5 points and decreased to 7 points, with a great decrease of 9 points. C3 Ecological protection status: To evaluate the development of industrial enterprises around the village that have an impact on the environment, it is best for all enterprises to move out and the worst is for the number of enterprises to increase year by year. The specific calculation steps of the evaluation system are as follows:

(1) Dimensionless treatment

Assuming that there are m evaluation objects and n evaluation indices in total, the matrix formula of the original entropy method is:

$$A = \begin{bmatrix} x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{bmatrix} = (x_{ij})_{n \times m} \quad (i = 1, 2, 3, \cdots\cdots m, j = 1, 2, 3 \cdots\cdots n) \tag{1}$$

In the formula, x_{ij} is the evaluation score of the indicator factor of item j by the i-th person.

Because each index has a different measurement unit, it is impossible to compare and analyze. Thus, the standard method of range was used to standardize the original data (Peng *et al.*, 2024), i.e. the index value was mapped to [0–1] to eliminate the influence of the original data due to the difference in dimensionality and variation range and to facilitate a comprehensive comparative analysis. The dimensionless adjustment formula for the numerical options of positive indicators is (a larger numerical standard is better):

$$X'_{ij} = \frac{X_{ij} - Min(X_{ij})}{Max(X_{ij}) - Min(X_{ij})} \tag{2}$$

The dimensionless adjustment formula for the numerical options of negative indicators is (a smaller numerical standard is better):

$$X'_{ij} = \frac{Max(X_{ij}) - X_{ij}}{Max(X_{ij}) - Min(X_{ij})} \tag{3}$$

In the formula, x_{ij} is the evaluation score of the indicator factor of item j by the i-th person; X'_{ij} is the value of x_{ij} after dimensionless processing; Max(x_{ij}) and Min(x_{ij}) are the maximum and minimum values among $i \times j$ values, respectively.

(2) Calculation of contribution P of each index factor score

The contribution degree of the scoring value is the proportion of data after the dimensionless evaluation of an index in the total dimensionless numerical scoring index of the index factor. The calculation formula is:

$$P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{n} X'_{ij}} \tag{4}$$

where x_{ij} is the evaluation score of the i-th person after the dimensionless index factor of the j-th item; P_{ij} is the contribution of the scoring data weight of the j-th index factor of the i-th respondent; n is the total number of respondents who participated.

(3) Calculation of the information entropy value e_j of the index factor score item

The information entropy value was calculated as follows:

$$e_j = -K * \sum_{i=1}^{n} \left(P_{ij} * \ln(P_{ij})\right) \tag{5}$$

where e_j is the total contribution of all respondents to the evaluation of the j-th index factor; n is the total population of the respondents; K ($K > 0$) is a constant and calculated as follows:

$$K = \frac{1}{\ln(n)} \tag{6}$$

where n is the number of samples.

Information entropy e_j is the degree of concentration of the index data of item j. More consistent evaluation values correspond to a higher degree of concentration.

(4) Determination of weight ω_j of the index factor score item.

To determine the evaluation weight of the index factors, we obtained the difference coefficient d_j of information entropy:

$$d_j = 1 - e_j \tag{7}$$

Then, the weight value of the factor score item was determined:

$$\omega_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{8}$$

where $j = 1, 2, 3, \ldots, m$.

4.5 Rural disaster resilience score and classification

(1) Comprehensive score calculation

After standardizing the indicators of the evaluation system and calculating the weights, one can calculate the score of the rural comprehensive score Z_i (Mailikai *et al.*, 2019) as follows:

$$z_i = \sum_{j=1}^{m} X'_{ij}\omega_j \tag{9}$$

In public notice (9), Z_i is the level of rural disaster resilience. When Z_i approaches 1, the disaster resilience level of the village is high and vice versa.

(2) Grading of rural resilience level

To make the rural resilience value more objective and comparable, combined with relevant research results, the disaster resilience level is divided into five grades with equal ranges (Jonas *et al.*, 2014). See Table 2 for details.

Table 2. Evaluation grade of rural disaster resilience in southern Xinjiang

Disaster resilience grade	Resilience index
Low resilience level (I)	[0,0.2)
Relatively low resilience level (II)	[0.2,0.4)
Moderate resilience level (III)	[0.4,0.6)
Relatively high resilience level (IV)	[0.6,0.8)
High resilience level (V)	[0.8,1)

4.6 Obstacle factor diagnosis

Obstacle diagnosis model is a tool to identify and analyze the key factors affecting the achievement of specific goals and the obstacles to their realization. This model helps decision-makers to define the improvement direction and optimization strategy by quantifying the negative impact of various factors on the goal realization. To further analyze the key factors affecting the resilience level of rural disasters in southern Xinjiang, this study uses the obstacle degree diagnosis model to identify the obstacles and constraints of rural resilience. The calculation formula is:

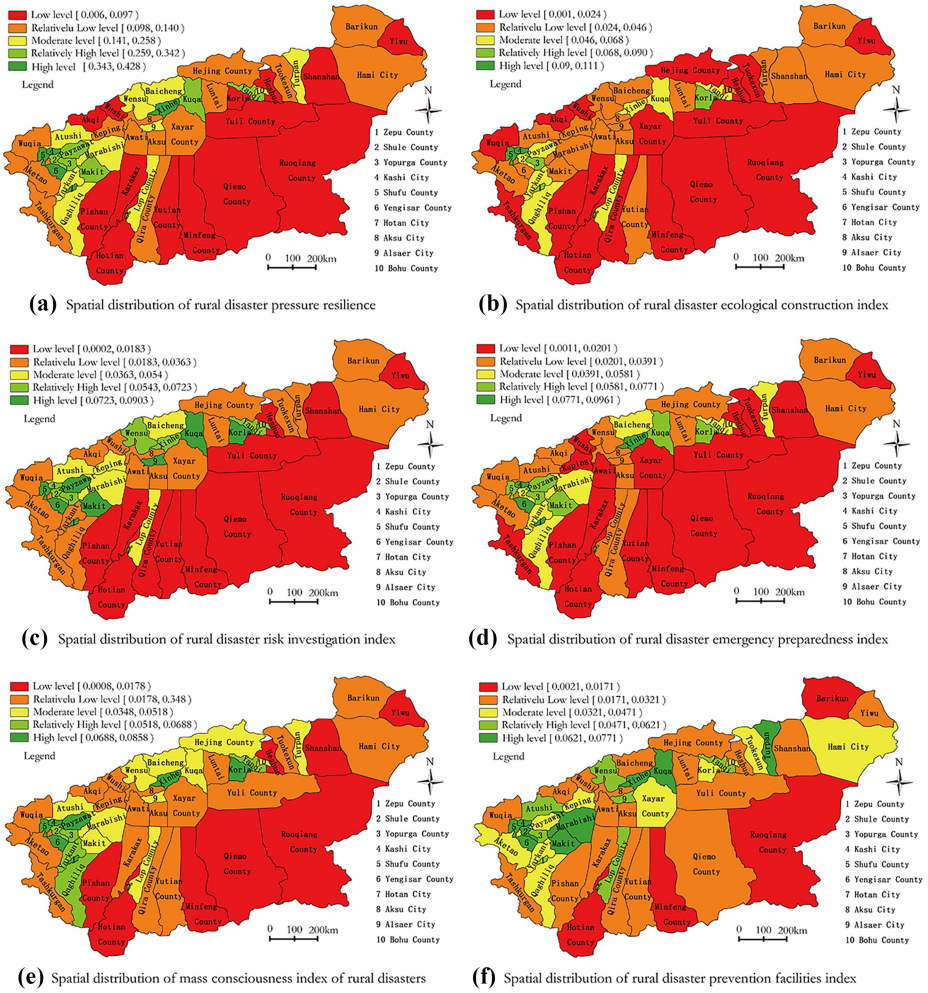
$$C_{ij} = \frac{(1 - x_{ij}) \times w_j}{\sum_{j=1}^{n} (1 - x_{ij}) \times w_j} \times 100\% \tag{10}$$

In formula (10), C_{ij} is the obstacle degree of the j-th index of the i-th village. A greater value of C_{ij} indicates that this index is a greater obstacle. w_j is the index weight of item j; x_{ij} is the standardized result of the j-th index of the i-th village.

5. Analysis of rural disaster resilience evaluation results in southern Xinjiang

5.1 Analysis of the resilience level of the rural pre-disaster pressure subsystem

The rural disaster pressure resilience level in southern Xinjiang has obvious spatial differentiation characteristics, which mainly shows that the pressure resilience level in the north and west of the Taklimakan Desert is high, whereas the pressure resilience level in the south and east of the desert is low. The overall trend is "high in the northwest and low in the southeast." Kashgar and its surrounding areas have higher disaster stress resilience, followed by Korla, which is the second-largest city in southern Xinjiang. Kashgar region and the Korla-Yanqi region are mainly flat terrain with distributed oases, more cultivated land and pasture resources, superior water and soil resources and relatively densest population. It has been a gathering place for residents in southern Xinjiang since ancient times. Combined with Figure 2, Ruoqiang County, Yuli County, Qiemo County, Shanshan County, Minfeng County, Yutian County, Pishan County, Aheqi County and Wushi County have the lowest disaster pressure resilience values, which indicates that these nine counties have suffered greater disaster safety pressure. An analysis of specific indicators shows that Shanshan County has made remarkable achievements in ecological construction and disaster-prevention facility construction due to the continuous investment of government funds in recent years. Ruoqiang County, Qiemo County, Minfeng County and Hotan County are the closest to the Great Desert, but the ecological construction, risk investigation, congestion preparation, people's awareness of disaster prevention and construction of disaster-prevention facilities in these four counties remain low. Compared with the other six counties, the people's awareness of disaster prevention and construction of disaster-prevention



(a) Spatial distribution of rural disaster pressure resilience

(b) Spatial distribution of rural disaster ecological construction index

(c) Spatial distribution of rural disaster risk investigation index

(d) Spatial distribution of rural disaster emergency preparedness index

(e) Spatial distribution of mass consciousness index of rural disasters

(f) Spatial distribution of rural disaster prevention facilities index

Figure 2. Analysis of resilience level of rural stress subsystem before disaster in southern Xinjiang

facilities in Wushi County and Aheqi County are relatively good, which shows that the propaganda and mobilization of disaster prevention in these two counties have achieved results.

5.2 Analysis of the resilience level of the emergency state subsystem in rural disasters

As Figure 3 shows, except for Minfeng County, Ruoqiang County and Qiemo County, the resilience level of rural disaster state subsystems in southern Xinjiang is relatively good as a whole and there is no very low resilience level. Among them, Turpan, Yanqi, Keping, Mo Yuxian and Luopu counties have high disaster state resilience values. This is related to the early implementation of key disaster-prevention measures in relevant counties and cities. Turpan has devoted itself to building a characteristic tourism industry in its early years with

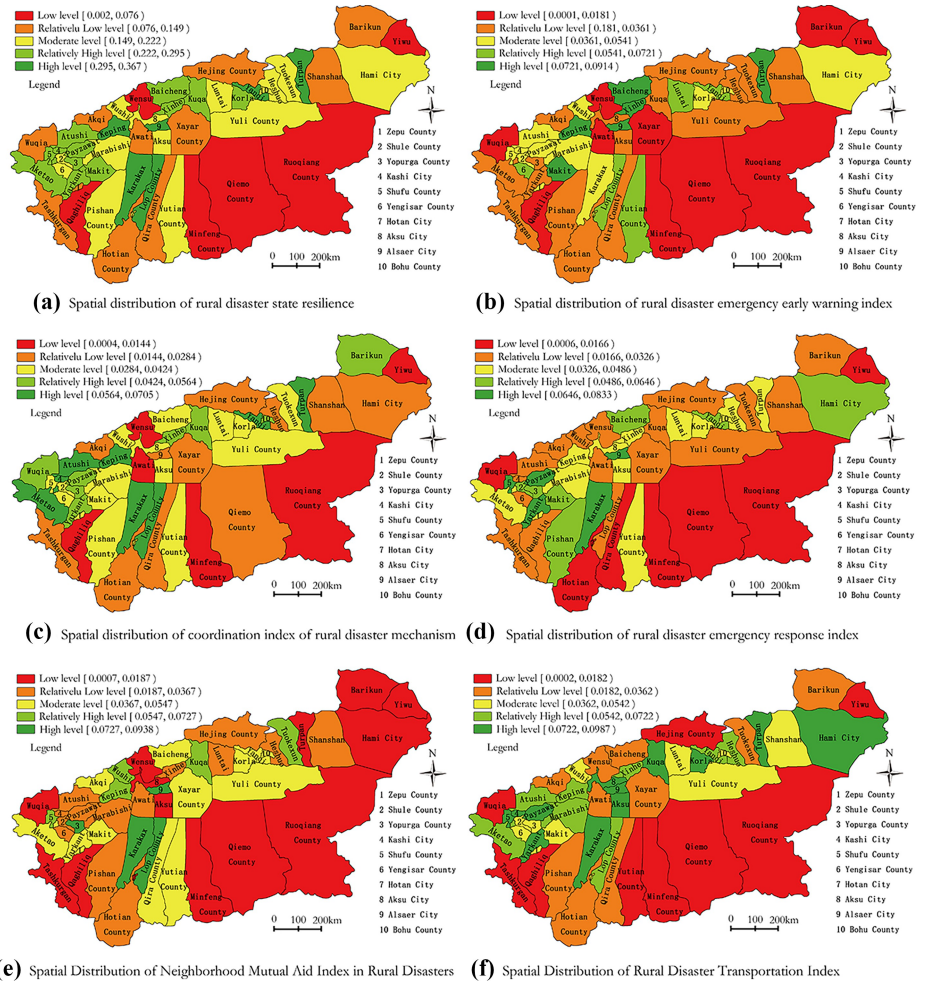


Figure 3. Analysis of resilience level of state subsystem in rural disasters in southern Xinjiang

relatively complete infrastructure and well-developed railway and highway systems, which are located on the main traffic routes between China and Xinjiang. The development and construction of these targeted measures undoubtedly played an important role in improving the resilience of rural conditions. Mo Yuxian and Luopu County have conducted earlier measures: implementing ecological restoration measures, such as pasture ecological subsidies and returning farmland to forests, developing rural disaster-prevention grid management systems, i.e. Sokcho sand fixation measures around the desert and guides villagers to pay for regular maintenance. Thus, they effectively improved the public's participation enthusiasm in disaster mitigation and prevention. All types of measures directly or indirectly make the countryside have stronger resilience and safe development ability for disaster prevention.

5.3 Analysis of the resilience level of rural post-disaster response subsystems

As Figure 4 shows, the overall resilience level of rural post-disaster response in southern Xinjiang is divided into three grades: low resilience, low resilience and general resilience. Kashgar-Artux, Korla and Baicheng-Kuqa have high response resilience and good post-disaster response degrees. The results show that the advantage of Kashgar-Artux and Korla lies in the good development of economic foundation, including village collective income and per capita income, which are significantly ahead of the average income of southern Xinjiang. The advantage of post-disaster responses in Baicheng County lies in its high welfare, which is closely related to the widespread popularization of social insurance and commercial insurance for local residents. From the perspective of the correlation between the resilience of security welfare, economic base and human security and the resilience of the overall response subsystem, the resilience of economic base and the resilience of the overall response subsystem have similar distribution patterns. Thus, the next step is to strengthen and enhance the resilience of rural disasters in terms of security welfare and human security, including increasing the proportion of rural participation in insurance and attracting young- and middle-aged people to return to the countryside.

5.4 Analysis of the resilience level of rural comprehensive disasters

The overall differentiation characteristics of the comprehensive resilience value of rural areas in southern Xinjiang are obvious. The overall trend is gradually weakening from the north and west of the Taklimakan Desert to the south and east of the desert. The surrounding villages in the Kashgar and Korla metropolitan areas have relatively strong comprehensive

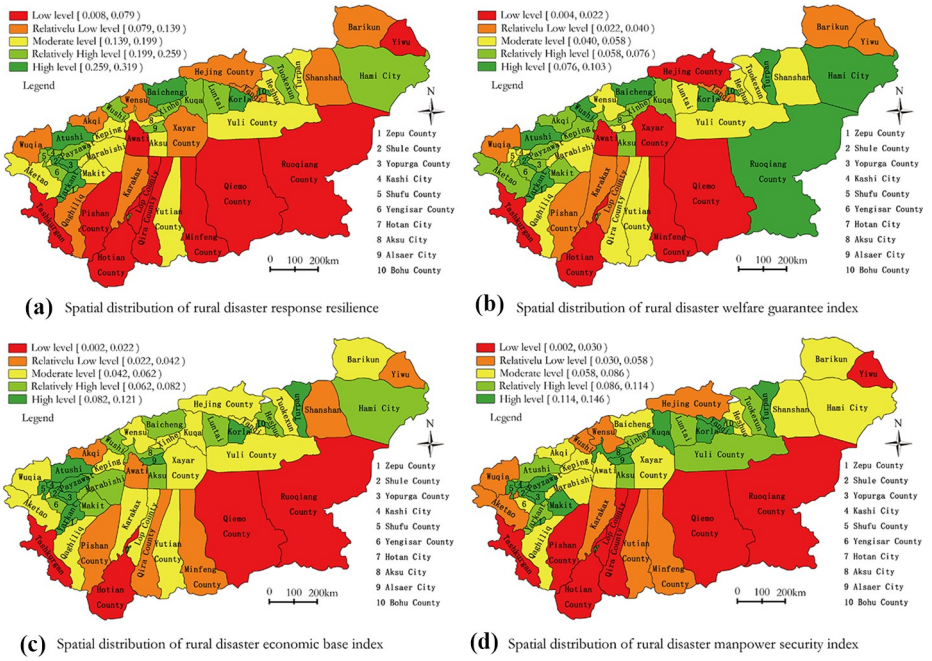


Figure 4. Analysis of resilience level of response subsystem in rural disasters in southern Xinjiang

resilience and Xinhe County at the foot of the Tianshan Mountain shows a small range of medium and high values of rural resilience (Figure 5). Thus, villages in the counties and cities in the northern and western parts of the Great Desert can maintain a relatively stable state in the ever-changing disaster environment and quickly restore the original functions and order of a rural system in the face of disaster impact and destruction. Through the distribution characteristics of rural comprehensive resilience, pre-disaster pressure resilience, post-disaster state resilience and post-disaster response resilience in southern Xinjiang, the pre-disaster pressure resilience value aggregation situation of rural areas and the spatial distribution pattern of rural comprehensive resilience are the most highly coincident. The comprehensive rural resilience level reflects the overall disaster resilience level of rural areas in southern Xinjiang under the PSR model, including pre-disaster defense pressure, post-disaster impact state and post-disaster recovery response. Its spatial distribution characteristics and quantitative evaluation of resilience level have important guiding significance for the fixed-point and directional improvement of rural disaster resilience in southern Xinjiang in the future.

5.5 Obstacle degree analysis

To clarify the obstacle factors of rural disaster resilience improvement in southern Xinjiang, this study uses the obstacle degree model to measure the obstacle degree of the rural disaster resilience evaluation index. According to the diagnosis method of obstacle factors, this work analyzes the obstacle factors of rural disaster resilience in 49 counties and cities in southern Xinjiang. Because of the large number of indicators, the top three factors that greatly affect disaster resilience were selected in this study. From the ranking of obstacles in each subsystem, the ranking of obstacles is pre-disaster defense pressure > emergency state in disaster > post-disaster recovery response. This shows that the main factor hindering the improvement of rural disaster resilience in southern Xinjiang is the pre-disaster defense

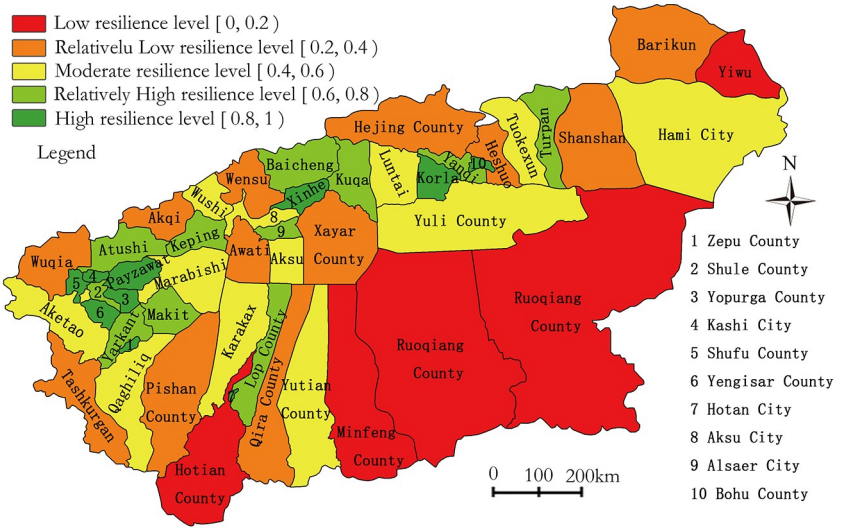


Figure 5. Analysis on resilience level of comprehensive disasters in rural areas of southern Xinjiang

pressure level, and the future development of resilience improvement can focus on the construction of rural defense capacity.

For example, the main obstacle factors that affect the resilience of rural disasters in Kashgar include the proportion of aging population (C31), the sources of surrounding hidden dangers (C7) and neighborhood disaster relief (C26). Among them, the proportion of the aging population (C31) is the biggest obstacle. The increasing proportion of aging population has always been an important factor that Kashgar and even China have to face. With the continuous transfer of rural agricultural population to cities and the sustained and rapid development of the national urbanization movement, the aging problem in rural areas is particularly serious, which has become a key factor in improving the resilience and safety of rural social disasters. Therefore, the proportion of aging population in rural areas of Kashgar restricts the level of human security and the ability to respond to disasters. Although the overall economic level in Kashgar, especially in the urban area of Kashgar, has developed well, it has also formed a siphon phenomenon for the young- and middle-aged population in the regional villages. A large number of young- and middle-aged rural people have left the countryside to live and work in cities and the countryside has become a high-populated area for the aging population and a high proportion of the aging population will inevitably affect the overall development vitality of the countryside. Because of the lack of young people, it is becoming more and more difficult for villagers to strengthen houses, repair houses, change gas and build roads, which may further limit the development of resilience in rural disasters in different degrees. The peripheral hidden danger source (C7) is the second biggest obstacle. Rural houses in Kashgar are mainly civil structures and the floors are wooden ribbed beams. Most of the exterior walls along the street are made of adobe and covered with wheat straw mud, which remains the same for decades or even hundreds of years, with poor seismic and fire resistance. Kashgar is located in the earthquake fault zone and there are serious security risks in rural houses (Wang and Hu, 2009). Although the earthquake-resistant reconstruction project of Kashgar residential buildings implemented since 2022 has enhanced the earthquake-resistant and disaster-prevention performance of suburban villages, the popularity of the reconstruction is not comprehensive, and many remote villages still cannot be involved, thus limiting the improvement of resilience. In addition, neighborhood disaster relief (C26) is also an important obstacle. Taking Kashgar as an example, the work of moving villages and merging points in recent years has caused many rural residents' neighborhoods to get acquainted with each other, and the original homesickness no longer exists, which has restricted the improvement of disaster resilience at the level of neighborhood mutual assistance.

6. Conclusions and recommendations

6.1 Conclusions

The results of this study provide a new idea for guiding and optimizing the disaster-resistant construction in rural areas of southern Xinjiang and will further accurately promote the realization of rural high-quality and resilient development goals. The specific conclusions are as follows:

The overall rural disaster resilience level in southern Xinjiang remains below the general level, and the spatial pattern of rural disaster resilience level has obvious differentiation characteristics. In general, it exhibits a "gradient" distribution characteristic of being lower in the east and south and higher in the west and north.

The high-value areas of rural disaster resilience are mainly concentrated in Kashgar on the western edge of the Taklimakan Desert and Korla in the north. The low-value areas are mainly distributed in the area of Minfeng County–Ruoqiang County in the east of the desert.

The top three indicators of rural resilience in southern Xinjiang are the proportion of the aging population, surrounding hidden dangers and the government's financial support for disaster prevention. From each subsystem of the evaluation system, the obstacle degree of rural disaster resilience level in southern Xinjiang is as follows: pre-disaster defense pressure > emergency state in disaster > post-disaster recovery response.

6.2 Recommendations

Our findings show that rural disaster resilience in southern Xinjiang has a clear spatial pattern. High resilience areas are mainly in Kashgar and Korla, while low resilience areas are in Minfeng County and Ruoqiang County in the east. The obstacle degree analysis shows that pre-disaster defense pressure is the biggest barrier, followed by emergency state and post-disaster recovery response. The top three obstacle indicators are the proportion of aging population, peripheral hidden dangers and financial support. These findings can directly guide local priorities by telling decision-makers where to act first (low resilience areas), what to act on first (pre-disaster defense) and how to act (targeting the top three obstacles). Based on this logic, we propose the following recommendations.

First, for low resilience areas such as Minfeng County and Ruoqiang County, local governments should make pre-disaster defense the top priority. This includes checking for peripheral hidden dangers around villages and improving disaster-prevention facilities. In our study, these two counties had low scores in land desertification control and emergency shelter availability. Therefore, we suggest building more disaster-prevention infrastructure in these places as a first step.

Second, for high resilience areas such as Kashgar and Korla, the main obstacle is still the aging population. Even though these areas have better economic conditions, many young people have left the countryside for cities. This reduces the manpower available for disaster response and recovery. We recommend that these areas develop rural industries to attract young people back. For example, supporting local agriculture or ecotourism could create jobs and keep the working age population in the villages. This would directly improve the human security dimension shown in our obstacle analysis.

Third, across all areas, financial support (C31) is a common obstacle. Our data show that many villages lack enough government funding for disaster prevention. We suggest that higher level governments increase special funds for rural disaster resilience, especially for early warning systems and emergency material reserves. At the same time, villages should be encouraged to use collective income for small scale resilience projects, such as repairing escape passways or organizing regular emergency drills.

Fourth, the obstacle ranking tells us that pre-disaster defense pressure is more important than post-disaster recovery response in southern Xinjiang. This means that spending money on prevention may be more effective than spending on recovery. We recommend that local disaster management plans put more resources into activities like disaster propaganda, emergency drills and building integrity checks. These actions target the indicators with high obstacle degrees, such as peripheral hidden danger sources (C7) and emergency drill frequency (C8).

By linking each recommendation to specific findings from our resilience evaluation and obstacle diagnosis, we hope to provide practical and targeted guidance for improving rural disaster resilience in southern Xinjiang.

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