Research on spatial optimization strategies of rural settlements in the Loess Plateau from the perspective of disaster prevention and reduction—A case study of Gaoxigou Village,China

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Abstract: The Loess Plateau is one of the regions with the most serious soil erosion and the most fragile ecological environment in the world. In recent years, the fragile rural settlement space is increasingly challenged by extreme weather, and various natural disasters occur frequently.Therefore, exploring spatial optimization strategies for rural settlements in this area from the perspective of disaster prevention and reduction is of great significance to ensuring the safety of residents and achieving sustainable development of rural settlements.Based on the results of natural disaster risk assessment in Gaoxigou Village, this paper analyzes the coupling relationship between different risk areas and various types of current village Spaces, and puts forward spatial optimization strategies from living space, ecological space and road space.

Keywords: Loess Plateau, rural settlement, spatial optimization

Introduction

In recent years, affected by factors such as global climate change and some human behaviors, urban and rural spaces have faced increasingly unstable threats of natural disasters. According to statistics from the United Nations Office for Disaster Risk Reduction, between 2000 and 2019, a total of 7,348 natural disasters were recorded around the world, causing 1.23 million deaths, a total of 4 billion affected people, and causing global economic losses of up to $2.97 trillion.In the urban and rural space, rural areas have the closest contact with the ecological environment and are therefore disaster-prone areas. However, at the same time, rural areas are the weakest areas in disaster prevention, reduction and relief, and their level of natural disaster prevention and control is relatively low. Therefore, studying the optimization of rural settlement space from the perspective of disaster prevention and reduction is of great significance for promoting rural safety development.

At present, the existing relevant research on disaster prevention and reduction is a combination of disaster systematics, economics and sociology. Through the research on the formation mechanism, occurrence mechanism, damage characteristics and disaster characteristics of various disasters, it combines social disciplines and population , social environment, economy, resources, etc., and for the purpose of disaster prevention and reduction, relevant technologies, measures and policy methods for disaster prevention and reduction are proposed.Scira Menoni evaluated the urban lifeline system from three aspects: organizational, physical and functional vulnerability, and proposed comprehensive planning and improvement of disaster prevention and reduction based on geospatial technology[1].Grange Ken quantitatively analyzes the influencing factors of snowstorm disasters from basic data, construction, material supply and community safety data, and studies ways to improve disaster prevention and reduction capabilities from the perspective of factors[2].Chi Tenglong, Zeng Jian, and Wang Sitong combined the actual conditions of the villages and took Zhujiaying Village in Fuping County as the research object. They analyzed the social, economic, natural and other development conditions of the village through data obtained from field surveys, identified development bottlenecks and safety hazards, and formulated Corresponding industry, site selection and village transformation strategies[3]. However, existing research currently lacks research on resisting and reducing disaster risks through spatial adjustment of potential disaster risks.

The Loess Plateau is a typical ecologically fragile area in my country, with criss-crossing ravines, broken surface, loose soil, and serious water and soil erosion. The depth of the channels in the area is 100-300m, and the average erosion intensity is about 10,000-25,000 tons/square kilometer per year, making the local ecological environment extremely fragile[4]. Under the influence of long-term natural conditions of strong winds, drought and little rain, rapid rainy seasons, and unreasonable utilization, rural settlements in the Loess Plateau face high ecological threats and frequent natural disasters. Therefore, conducting research on the optimization strategies of rural settlement space in this region from the perspective of disaster prevention and reduction has strong practical significance in guiding the optimization of rural space in this region, improving the ability to withstand disaster risks, and achieving sustainable rural development.

1. Reflection on practical issues in rural settlements on the Loess Plateau

The Loess Plateau is located in the northern part of central China, spanning seven provinces and regions: Qinghai, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, and Henan. It has an altitude of 800 to 3,000 meters and a total area of 640,000 square kilometers.The Loess Plateau is a highly ecologically sensitive area and one of the areas with the most severe soil erosion in the world. It is soil erosion area reaches 230,000 square kilometers, accounting for thirty-four percent(34%) of the Loess Plateau's land area. In addition, the area has been severely eroded by running water for a long time, gradually forming a special natural landscape with thousands of ravines and fragmented terrain. The ravine density is about 2.35-10.9km/km^2. It has typical loess collapsible geological characteristics and various natural disasters occur frequently. With the continuous advancement of urbanization, urban and rural construction space has further expanded. In addition, this area is an important energy base in China and the area with the greatest coal production potential. Its rich mineral and tourism resources have further promoted the industrial, mining and cultural tourism industries in the area. These reasons have increased the human disturbance of the originally fragile ecological environment.

In recent years, as the global precipitation line gradually moves northward, rainfall continues to increase, and rainfall changes significantly in space and time. In addition, regional instantaneous rainfall in summer is relatively large, which has led to a significant increase in local natural disaster risks. Rural areas are disaster-prone areas, and they are the weakest link in disaster prevention, reduction, and relief. With the continuous advancement of urbanization and the rapid changes in village production and lifestyle, ecologically fragile rural settlements are facing more severe disasters. As a result, rural settlements on the Loess Plateau will face greater disaster threats in the future. Therefore, how to deal with the impacts of fragile ecological background, increased human disturbance, and intensified climate change and minimize disaster risks has become the biggest practical problem facing rural areas on the Loess Plateau.

2. Optimization path of rural settlement space in the Loess Plateau from the perspective of disaster prevention and reduction

Climate change and the original fragile background conditions have caused local rural settlement space to face a high degree of threat. First, local disaster risks were assessed based on factors such as slope, slope aspect, slope type, rock formation, and disaster development density. Then, based on the risk assessment results, a rural space optimization strategy is proposed to reduce the impact of disasters from three aspects: ensuring residential safety, enhancing ecological service functions, and improving road emergency capabilities.

First of all, in terms of residential safety, by identifying areas where medium and high risk areas conflict with the current living space, the layout of the living space is adjusted to avoid medium and high risk areas, and at the same time, hidden danger points of residential disasters are rectified to ensure the safety of residents.Secondly, in terms of ecological space, through coupling analysis of the current ecological space and different disaster risk levels, the functions of ecological space are re-adjusted, and through potential ecological hydrological analysis, the breaking points of ecological space are repaired and the overall service function of rural ecological space is improved.Finally, in terms of road space, the medium and high-risk areas of the existing roads will be renovated, and the road system will be reorganized to improve the emergency disaster relief capabilities of the roads.

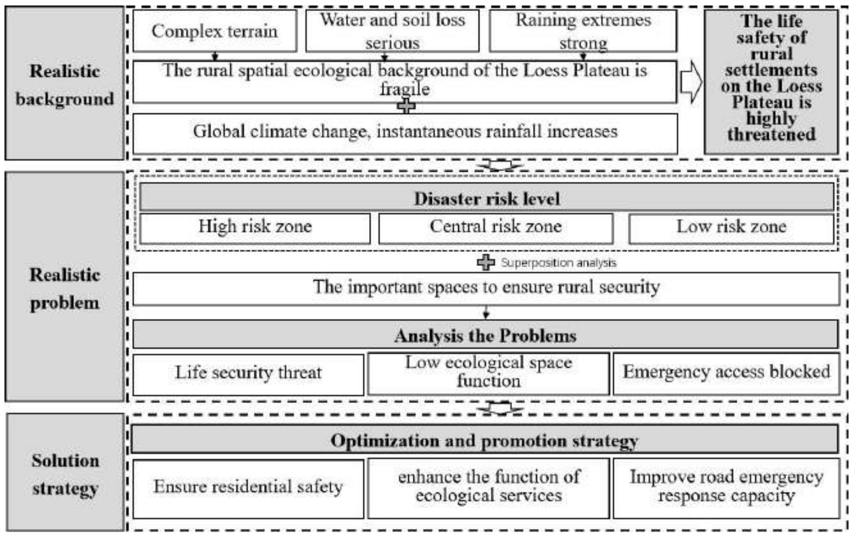

Fig. 1 Rural settlement optimization path

3. An empirical case of spatial optimization in Gaoxigou Village from the perspective of disaster prevention and reduction

3.1 Overview of research objects

Gaoxigou Village is a typical Loess Plateau area located in Mizhi County, Yulin City, Shaanxi Province, China, with a total area of 406.93 hectares. There are 40 mountains in the village. The terrain in the village is undulating and fragmented. The density of ravines is about 5-7 kilometers per square kilometer, and the depth of the gullies is between 100-200 meters. In recent years, with the increase in rainfall, geological disasters such as landslides and collapses have occurred frequently, posing a high threat to the safety of residents' production and life.

Based on the data from the Xi'an Geological Survey Center of the Bureau of Geological Survey, combined with factors such as slope, slope aspect, slope type, rock group, and disaster development density, the Gaoxigou disaster risk area and level were comprehensively evaluated. The evaluation results show that the village area with high disaster risk covers an area of 19.41 hectares, accounting for four point eight percent(4.8%)of the study area. It is mainly distributed on both sides of the ditch, close to the bottom of the ditch, and distributed in a dendritic shape;the medium-risk area is 51.65 hectares, accounting for twelve point six nine percent(12.69%) of the study area, mostly adjacent to high-risk areas and distributed on the slopes on both sides of the ditch; the low-risk area is 335.87 hectares, accounting for eighty-two point five one percent(82.51%) of the study area, and is widely distributed, mainly in areas with gentle slopes within the village.

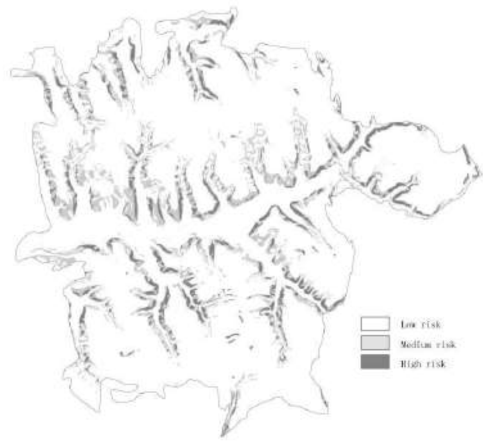

Fig. 2 Disaster risk zoning in Gaoxigou Village

3.2 Analysis of real problems

3.2.1 Lack of planning for living space and high threat to life safety

The risk assessment results were superimposed on the current construction space to identify residential space and medium-risk and high-risk conflict areas.Among them, 15 high-risk residences are located on the north side of the village, 5 of which are located in the main channel of the village, and the remaining 10 are located in the village.There are 27 medium-risk houses in the branch ditch, 2 are located on the north side of the main ditch, 10 are located in the branch ditch on the south side of the village, and 15 are scattered in the north side ditch.

In addition, after on-site investigation, it was found that although some residential spaces are not in medium-risk or high-risk areas for geological disasters, due to the special loess type and the cutting of slopes for building houses, some residences still have disaster hazards.Through household surveys, it was found that 8 houses in the village located in low-risk areas in the branch ditches on the north and south sides of the village still have potential disaster safety risks.

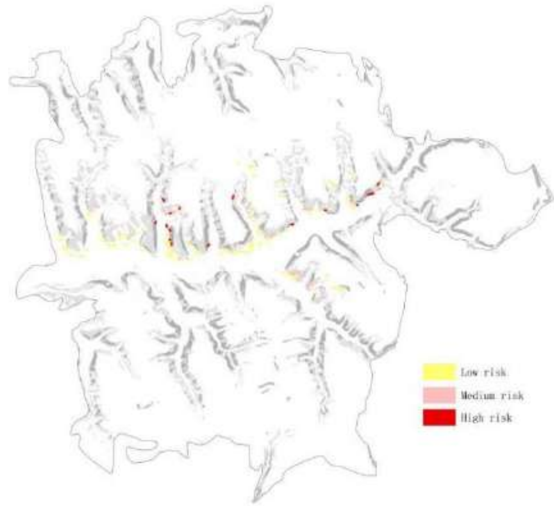

Fig 3. Construction disaster risk level

Fig 4. Hidden danger points of construction disasters in low-risk areas

3.2.2 The ecological environment is fragile and the functional efficiency of ecological space is low

The woodland, grassland, pond water surface, and inland tidal flats within the village area were extracted as ecological land, with an ecological land area of 217 hectares.Superimposing disaster risk zoning and ecological space, the coupling area of high-risk areas and current ecological space is 16.30 hectares, with a coupling degree of approximately eighty-four percent(84%), the coupling area of medium-risk areas with ecological space is 33.05 hectares, and the coupling degree is approximately sixty-four percent(64%).The degree of coupling between medium and high risk areas and the current ecological space is at a medium level.This shows that the coupling relationship between ecological space and disaster risk in this region is fragile, and it is necessary to further improve its coupling degree and disaster resilience through ecological space adjustment.

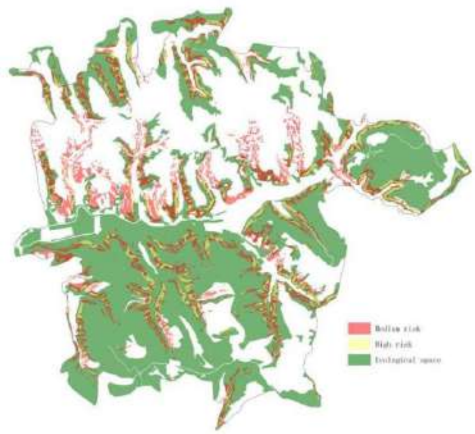

Fig 5. Coupling situation of ecological space and medium- and high-risk disasters

In addition, the local ravines are criss-crossed and the instantaneous rainfall is large. Therefore, the gully space assumes the drainage function during the rainy season and is a potential hydrological space.Through GIS spatial analysis, this paper extracts the hydrological space of three levels in Gaoxigou and compares the ecological space with the hydrological space.Superimposing ecological space and hydrological space, it was found that there are fractures in the existing three-level hydrological space. Among them, the length of the first-level hydrological space is about 3.04km, the length of the second-level hydrological space is about 2.93km, and The length of the third-level hydrological space fault is approximately 1.93km.

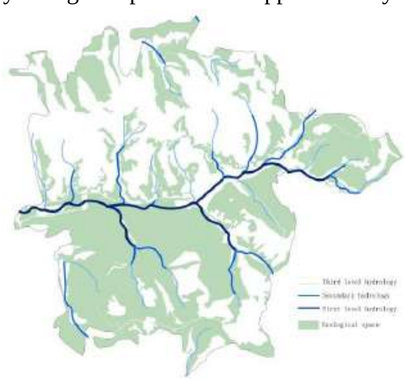

Fig 6. Current status of hydrological spatial distribution and systematics

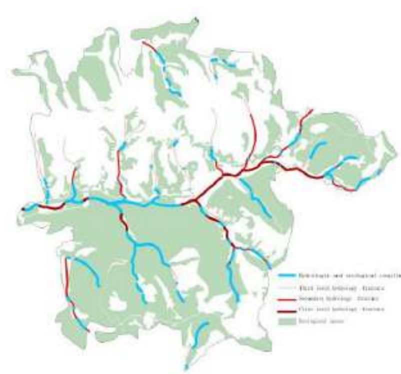

Fig 7. Current status of hydrological space fractures

3.2.3 Road space is not smooth and emergency and disaster relief capabilities are *insufficient*

Through the overlay analysis of the existing roads and disaster risk areas in the village, it was found that the existing roads do not have high-risk hidden dangers, but there are moderate-risk hidden dangers in disasters, with the risk area being about 0.39 hectares.In addition, the road space on the Loess Plateau serves as an important lifeline and plays an important emergency rescue function.However, there are many dead-ends roads and the road network cannot meet the needs of emergency rescue.

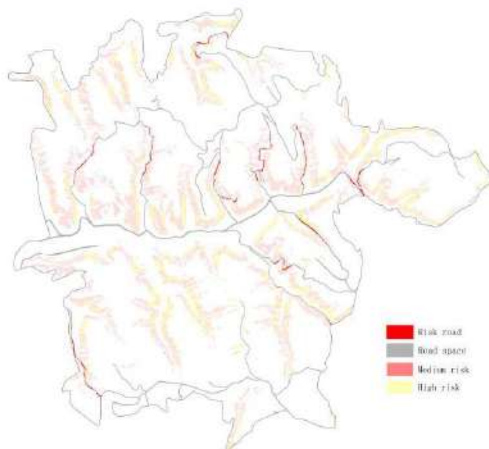

Fig 8. Road disaster risk levels and distribution

4. Space optimization strategy of Gaoxigou Village from the perspective of disaster prevention and reduction

4.1Ensure residential safety

Based on the overlay analysis of residential space and risk areas, the buildings located in high-risk areas are relocated and set aside. Corresponding safety precautions should be taken for areas that are temporarily unavailable to move out, and construction and expansion should be strictly controlled to cause the area to shrink, and ecological restoration should be carried out to gradually restore it to an ecological space.For buildings located in medium-risk areas, ecological retreat can be adopted. On the premise of ensuring safety, the ecological space can be gradually returned by changing the use of the building. For example, it can be used as agricultural housing in the early stage, and the ecological space can be gradually returned to the ecological space as time goes by.

Fig 9. The building layout adjustment

Tab1. Construction risk control measures

Risk source number	Suggestions on risk management and control measures
1	Conduct regular inspections, strengthen monitoring
2	Conduct regular inspections, Clear dangerous rock mass
3	Conduct regular inspections, strengthen monitoring, surface drainage
4	Conduct regular inspections and strengthen monitoring
5	Conduct regular inspections, strengthen monitoring, surface drainage
6	Conduct regular inspections, strengthen monitoring, surface drainage
7	Conduct regular inspections, strengthen monitoring, surface drainage
8	Conduct regular inspections, strengthen monitoring, Clear dangerous rock mass, surface drainage

4.2 Enhance ecological service functions

Based on the risk assessment results, the functions of the existing ecological space should be rearranged. For ecological spaces located in high-risk disaster areas, priority should be given to protecting and maintaining the integrity and functionality of the ecosystem.A strict ecological protection system should be implemented, and any form of farming and construction activities should be strictly prohibited and implement enhanced management measures. For ecological spaces located in medium-risk areas, ecological spaces for productive restoration can be set up. During the development process, terraces can be constructed to effectively reduce the speed and amount of rainwater runoff, and some fruit tree varieties with better soil-fixing capabilities can be selected to grow. At the same time, some fruit tree varieties with better soil-fixing capabilities can be chosen to plant. This can reduce soil erosion while increasing the scale of agricultural production land. For ecological spaces located in low-risk areas, without destroying their ecological integrity, by combining them with local natural and ecological values, they should appropriately incorporate sightseeing, recreation and other functions, which not only ensures that the ecological environment is effectively protected and restored, but also Significantly improve residents' quality of life.

In view of the actual situation of ecological fracture points, ecological land restoration is required for the fracture areas of the primary hydrological space, and strict ecological priority policies should be implemented. At the same time, the buildings already constructed in the fracture areas should be demolished, and the current production land in the fracture areas should be returned to forest and grassland to ensure the continuity of the primary hydrological space and ecological security.

4.3 Improving road emergency response capabilities

Combined with the results of road risk identification, for road spaces located in medium-risk areas, it is necessary to comprehensively consider the actual road conditions, select appropriate protection measures, prevent the occurrence of disasters such as landslides and collapses, and deal with potential risks in a timely manner to ensure smooth and safe roads.First of all, these road disaster risk types are mainly landslides and collapses. According to the disaster types, the stability of road slopes can be strengthened by using slope protection forms such as mortar-laid stone, mesh shotcrete, and mesh sprayed ecological technology to effectively prevent disasters.At the same time, by strengthening patrol supervision, regularly checking road conditions, and promptly discovering and resolving potential hidden dangers, we can ensure that the roads are always in good condition and provide residents with a safe and smooth travel environment.

In addition, the road system within Gaoxigou Village was reorganized, dead-end roads were opened up, and a circular series road system that conforms to the terrain was adopted. This will help increase the redundancy of emergency escape routes and effectively improve the road emergency response capabilities.While providing villagers with more convenient and safer travel conditions, rescue operations can be launched more quickly when faced with emergencies, thereby improving the village's overall disaster prevention and relief capabilities and protecting the lives and property of villagers.

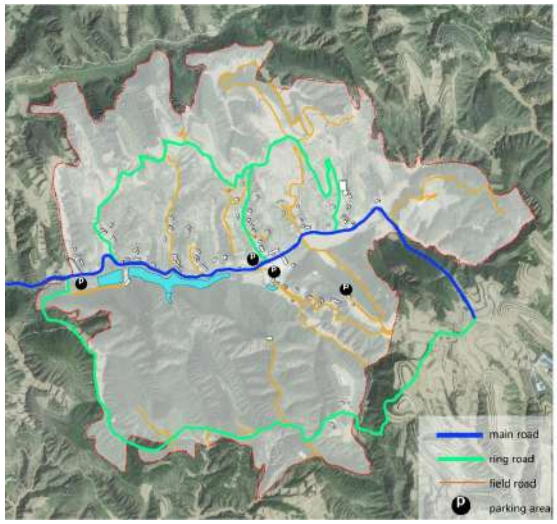

Fig 10. Reorganization of road traffic system

5. Conclusion

Combined with the results of the disaster risk assessment of Gaoxigou Village, the residential space, ecological space and road space in the village were coupled and superimposed, and it was found that there were real problems such as hidden dangers to residential safety, broken ecological space, and insufficient road emergency support capacity in the village.In response to practical problems, a village optimization strategy is proposed to ensure residential safety, enhance ecological service functions and improve road emergency response capabilities, thereby reducing local disaster risk threats and effectively ensuring the safety of residents. Overall, this idea is highly applicable to rural settlements in the Loess Plateau where the ecological background is fragile.

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