# Building a Collaborative Model for Comprehensive Disaster Mitigation and Characteristic Industries in Mountainous Areas to Foster High-Quality Development of China' s Mountainous Regions (Postprint)

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## Abstract

In China, mountain disaster-prone areas and economically and socially underdeveloped regions exhibit a high degree of spatial overlap. The long-standing disconnect and disengagement between disaster reduction and development has resulted in tremendous resource waste, becoming a key obstacle hindering the synchronized modernization of mountainous areas by 2035. Based on a systematic review of the major challenges facing integrated disaster reduction and industrial development in mountainous areas, this article innovatively develops a "disaster-land-human" green coordination theory for disaster-prone mountainous areas based on the human-land coordination concept, proposes new concepts and models for the coordinated development of integrated disaster reduction and characteristic industries, and analyzes the internal and external coordination mechanisms, main coordination pathways, and key coordination technologies of this model. The construction achievements of the coordinated demonstration zone for integrated disaster reduction and industrial development in the Reshuihe small watershed of Hongmo Town, Xide County, Liangshan Yi Autonomous Prefecture, Sichuan Province, are systematically introduced. The necessity, feasibility, and specific pathways for promoting the coordinated model of integrated disaster reduction and industrial development in mountainous areas nationwide are discussed. The results can be used to guide the consolidation of poverty alleviation achievements and the comprehensive implementation of rural revitalization strategies in China' s vast mountainous areas, and also help improve the overall planning and governance capacity of mountainous areas, supporting their modernization construction.

# Full Text

## Preamble

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## Title and Authors

### Building a Synergy Model for Integrated Disaster Risk Reduction and Characteristic Industries to Promote High-Quality Development in China' s Mountain Areas

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## Abstract

In China, the spatial distribution of mountain disaster-prone areas overlaps significantly with regions lagging in economic and social development. The long-standing disconnect between disaster risk reduction and development has caused tremendous resource waste and become a critical obstacle preventing mountain areas from achieving modernization in sync with other regions by 2035. This paper systematically examines the main challenges facing integrated disaster risk reduction and industrial development in mountain areas. Building upon the human-environment harmonization theory, we innovate the "Disaster-Environment-Human" green synergy theory for disaster-prone mountain regions, proposing a new concept and model for synergizing disaster risk reduction with characteristic industrial development. We analyze the internal and external synergy mechanisms, main synergy pathways, and key synergy technologies of this model. The paper systematically introduces the achievements of the demonstration zone for synergy between disaster risk reduction and industrial development in the Reshui River watershed, Hongmo Town, Xide County, Liangshan Yi Autonomous Prefecture, Sichuan Province. Finally, we discuss the necessity, feasibility, and specific pathways for promoting this synergy model across mountain areas nationwide. These results can guide the consolidation of poverty alleviation achievements, advance the implementation of rural revitalization strategies, improve comprehensive governance capabilities in mountain areas, and support their modernization efforts.

**Keywords**: mountain areas, disaster risk reduction, ecological disaster mitigation measures, poverty alleviation, sustainable development

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China is a major mountainous nation, with mountains covering approximately 64.9% of its total land area and supporting a permanent population of about 330 million, where the vast majority of ethnic minorities reside. The extensive territory, large population, abundant natural resources, profound historical and cultural heritage, and tremendous development potential make mountain areas the most important "rear garden" supporting national sustainable development, while their strategic position is also particularly critical. However, the unique energy gradient characteristics of mountain areas, combined with intensified human activities and increased extreme weather and climate events in recent years, have caused natural disasters such as landslides, debris flows, flash floods, and droughts to exhibit new activity patterns characterized by large spatial extent, high frequency, and large scale. These disasters not only threaten ecological, environmental, and livelihood security in mountain areas but also cause residents to fall into or return to poverty due to disasters, becoming a primary obstacle to sustainable development in these regions. Consequently, resource-rich mountain areas have paradoxically become regions with relatively lagging economic and social development nationwide.

Therefore, reducing disaster risk in mountain areas constitutes the fundamental guarantee for building a harmonious and shared human-nature pattern and achieving sustainable economic and social development. The Chinese government attaches great importance to disaster prevention and mitigation, having established the National Disaster Reduction Committee to oversee disaster reduction efforts and integrated responsibilities from multiple ministries to form the Ministry of Emergency Management, providing efficient organizational guarantees for addressing complex disaster issues and enhancing disaster prevention and mitigation capabilities. China has also innovated its guiding ideology for disaster prevention and mitigation, proposing the "Two Adherences, Three Transformations" policy as the basic guideline for disaster prevention, mitigation, and relief work in the new era. In recent years, disaster prevention and mitigation science has developed rapidly, giving rise to a series of new ideas and concepts for coordinated natural disaster risk management, significantly improving monitoring, early warning, comprehensive management, emergency response, and grassroots disaster prevention capabilities. According to the Ministry of Natural Resources, in 2022, China successfully forecast 905 geological disasters of various types, avoiding potential casualties of over 25,000 people. During the 13th Five-Year Plan period, casualties caused by mountain disasters decreased by 77.4% compared to the 11th Five-Year Plan period, successfully ensuring the safety of mountain residents. With strong support from a series of policies including urban-rural integrated development, land transfer, and poverty alleviation, China' s mountain areas have also achieved historic accomplishments in economic and social development. Historic victory has been achieved in poverty alleviation, bringing fundamental changes toward comprehensive moderate prosperity; infrastructure has developed rapidly, significantly improving production and living conditions; industrial structure has been notably optimized; and modernization has steadily advanced.

Despite these historic breakthroughs in disaster prevention and mitigation capabilities and economic and social development levels in China' s mountain areas, the basic national condition of frequent, multi-type, and recurrent natural disasters persists. The spatial overlap between high-risk disaster zones and lagging economic and social development zones remains extensive, leaving mountain areas facing dual pressures of disaster reduction and development, with the extremely severe reality showing no significant change. During long-term poverty alleviation practices, scholars have paid considerable attention to poverty caused and exacerbated by disasters. Some have also explored comprehensive disaster risk prevention from a new perspective of geographical synergy theory, proposing paradigms and pathways to achieve "human-environment synergy." However, neither institutionally nor ideologically has disaster prevention and mitigation been fundamentally integrated with regional economic and social development initiatives represented by poverty alleviation, resulting in a persistently high risk of large-scale returns to poverty in medium- and high-risk disaster areas. Achieving basic socialist modernization by 2035 represents a critical step toward the second centenary goal after building a moderately prosperous society in all respects. For China' s vast mountain areas, realizing this goal faces enormous challenges.

Based on the above analysis, this paper addresses the long-standing disconnect between disaster risk management and economic and social development in China' s mountain areas. We systematically examine the main challenges currently facing comprehensive disaster risk regulation and mountain area development, propose a new concept for synergizing disaster risk reduction with characteristic industrial development, and systematically analyze the construction of China's first demonstration base for synergy between disaster risk reduction and industrial development in the Reshui River basin, Hongmo Town, Xide County, Liangshan Yi Autonomous Prefecture, Sichuan Province. Finally, we attempt to propose specific pathways for promoting this synergy model across mountain areas nationwide. We hope these research results can provide direct reference for consolidating poverty alleviation achievements and comprehensively promoting rural revitalization in China' s vast mountain areas, while also helping to improve comprehensive governance capabilities and support safe and high-quality development in mountain areas.

## 1. Main Challenges Faced by Integrated Disaster Risk Reduction and Industrial Development in Mountain Areas

Natural disasters that occur frequently and in multiple forms represent one of China' s basic national conditions. China is among the countries most severely affected by natural disasters worldwide, with rare historical longevity, extensive affected areas, diverse disaster types, and severe disaster conditions globally. Taking mountain disasters as an example, the vast majority of China' s mountain areas have suffered from mountain disasters such as flash floods, debris flows, and landslides to varying degrees [Figure 1: see original paper], with some exhibiting chain and clustered characteristics, causing severe losses. For instance, the 2013 extreme rainstorm disaster event in Sichuan triggered clustered flash floods, debris flows, and landslides in 12 counties (cities) including Wenchuan, causing over 200 deaths and disappearances, damaging 30%–40% of houses, destroying 28,000 mu of farmland, damaging extensive infrastructure, and resulting in direct economic losses exceeding 40 billion yuan. On June 26, 2020, a large-scale flash flood and debris flow struck the northern mountainous area of Mianning County, Liangshan Yi Autonomous Prefecture, Sichuan, affecting 2,100 households with over 9,880 people, causing 22 fatalities, damaging 15,000 mu of crops, severely collapsing 174 houses (661 rooms), and destroying numerous infrastructure facilities and characteristic industries, with direct economic losses reaching 738 million yuan. In this disaster, 87 registered poverty-stricken households were severely affected, involving 417 impoverished people with family asset losses of 3.53 million yuan.

Disaster risk reduction in mountain areas urgently needs to break through the traditional concept dominated by geotechnical engineering measures and establish green regulation technologies and models for disaster-causing risks to support green development. Although the existing disaster prevention and mitigation system centered on engineering measures has achieved remarkable results in reducing disaster losses, geotechnical engineering measures are constrained by their service life, severely affecting the sustainability of mitigation benefits. In contrast, the benefits of ecological engineering measures for disaster mitigation increase over time, effectively compensating for the limitations of geotechnical measures. Therefore, there is an urgent need to scientifically configure ecological and geotechnical engineering measures based on scientific understanding of disaster formation and mechanisms, giving full play to their respective mitigation benefits to form scientific and efficient risk prevention technologies and models. This would enhance overall disaster prevention and mitigation capabilities, promote regional ecological environment improvement, and meet national needs for serving "ecological civilization" and "Beautiful China" construction.

The relatively lagging development of characteristic industries in mountain areas, which has not been closely integrated with disaster risk reduction needs, has become a major obstacle to high-quality economic and social development. During the poverty alleviation period, most industrial projects were concentrated in traditional agriculture and animal husbandry with relative resource advantages, largely referring to cultivation and management models from surrounding regions. Characteristic industries with local features and high added value have not been fully developed, resulting in product homogenization, low market prices, and sales difficulties, causing farmers to increase production without increasing income and dampening their enthusiasm for agricultural production. Some local village collective economies remain weak, with poverty alleviation funds being small and scattered, causing previously cultivated characteristic industries and key products to exhibit short-term characteristics that prevent industries from becoming strong and large-scale. Planning for characteristic industries seldom considers watershed-wide disaster risk reduction needs, leaving industrial development insufficiently resilient to various natural disasters and lacking substantive contributions to watershed-wide disaster risk reduction.

The long-standing disconnect between integrated disaster risk reduction and characteristic industrial development has caused tremendous resource waste, urgently requiring exploration of synergy mechanisms and models between them. Influenced by China's basic geographical conditions of frequent, multi-type, and recurrent natural disasters, ensuring safety and promoting development have become common tasks facing the vast majority of mountain areas nationwide. Particularly, disaster prevention, mitigation, and relief as the main content of safety assurance often consume substantial human, material, and financial resources, seriously hindering development goals. Taking Liangshan Yi Autonomous Prefecture in Sichuan Province—a region with medium to high risk of forest fires and mountain disasters—as an example, local governments at all levels basically operate in a state of "fire prevention in the first half of the year, flood prevention in the second half," with grassroots personnel bearing heavy tasks and local people finding it difficult to achieve prosperity. For medium- and high-risk mountain areas, there is an urgent need to synergize disaster risk management capacity improvement, ecological environment improvement, and characteristic industrial development. A key technology system for green regulation of disaster risk must be developed that integrates disaster-causing risk green regulation technology, ecological environment improvement technology, and regional characteristic industrial development technology, forming a green sustainable development technology system and model that synergizes ecological measures with engineering measures and coordinates comprehensive disaster risk management with regional sustainable development. This would meet the needs of ecological environment quality improvement and characteristic industrial development in the upper and middle reaches of small watersheds, as well as rural revitalization and sustainable economic and social development in the lower reaches.

## 2. Synergy Concept for Integrated Disaster Risk Reduction and Characteristic Industrial Development in Mountain Areas

Academician Wu Chuanjun' s theory of human-environment regional systems emphasizes regional functionality, systematic structure, spatiotemporal variation processes, and the differences and controllability of human-environment system effects, forming the theoretical cornerstone for comprehensive research on geographical pattern formation and evolution. The human-environment harmonization theory, developed from this foundation, advocates analyzing the close relationship between humans and the environment to achieve harmony and unity between the natural environment and human production and life. For medium- and high-risk disaster mountain areas, various natural disasters have become key factors constraining local sustainable economic and social development, with disaster, environment, and human elements together constituting the core elements of the regional human-environment regional system. Therefore, comprehensively considering these three elements and proposing a green synergy theory and methodology system for "Disaster-Environment-Human" represents both a further development of human-environment regional system theory and a more effective approach for exploring the coordinated and interactive relationships among the three elements. This meets the practical needs for green regulation of disaster risk and supports the construction of safe, prosperous, and beautiful mountain areas [Figure 2: see original paper].

Compared with human-environment harmonization theory, the "Disaster-Environment-Human" green synergy theory places greater emphasis on maintaining the green essence of mountain disaster risk regulation. Greenness represents the lifeblood of mountain systems, and the key to solving safety and development issues in mountain areas lies in ecological construction and green development. Specifically, for different objects of "disaster," "environment," and "human," synergy can be promoted through three aspects: green disaster reduction engineering (for the "disaster" element), green industrial development (for the "environment" element), and comprehensive risk management (for the "human" element), thereby achieving both internal and external synergy and the ultimate goal of coordinated disaster risk reduction and industrial development. First, internal synergy: Green disaster reduction engineering emphasizes ecological-geotechnical collaborative management and monitoring-forecasting collaborative early warning. Through systematic disaster management projects, monitoring and early warning projects, and land consolidation and protection projects, it achieves comprehensive regulation of disaster risk and creates new safe and usable production and living spaces. Green industrial development focuses on spatial synergy of various industrial layouts, synergy of industrial types, and synergy of protection and development. By conducting green industrial planning, supporting infrastructure construction, sustainable development and utilization of disaster-destroyed sites, and building a green disaster reduction industry model system, it achieves integrated industrial development. Risk management emphasizes synergy among various management measures, including developing multi-level, cross-departmental, and multi-stakeholder disaster risk management systems and mechanisms, focusing on risk information management, and conducting safe community construction to enhance grassroots government disaster risk management levels and improve public disaster perception and response capabilities. Second, external synergy: This emphasizes mutual promotion among the three elements, where disaster management sustains green industrial development and community safety, green industrial development reduces disaster material sources and increases economic income, and risk management enhances residents' awareness and initiative in disaster prevention and green development [Figure 3: see original paper].

## 3. Key Synergy Technologies for Integrated Disaster Risk Reduction and Industrial Development

### 3.1. Territorial Spatial Planning Technology Based on the Synergy Concept of Disaster Risk Reduction and Industrial Development

China is currently promoting territorial spatial governance capacity building led by territorial spatial planning, aiming to form a territorial spatial development and protection system based on territorial spatial planning and unified use control by 2025, achieving a "one map" approach to national territorial spatial development and protection. For the vast mountain areas prone to frequent natural disasters, there is an urgent need to integrate the synergy concept of disaster risk reduction and industrial development throughout the entire process of territorial spatial planning at all levels. This requires not only giving priority to natural disaster factors as constraints on human settlement construction and economic and social development in the "dual evaluation" system, but also applying the green synergy concept to various scenarios such as territorial "production-living-ecological space" layout, territorial spatial use control, and planned land use structure allocation, while scientifically diagnosing the degree of territorial spatial development and utilization. Key technologies involved in this process include small watershed disaster risk assessment technology, territorial spatial development suitability evaluation and optimization technology, integrated disaster risk reduction and industrial development collaborative planning technology, and territorial spatial development and utilization degree diagnosis technology, in order to ensure synergy between disaster risk reduction and industrial development from the planning level.

### 3.2. Key Technologies and Models for Green Disaster Reduction Engineering with Synergy of Ecological and Geotechnical Measures

Breaking through the existing concept of disaster reduction engineering dominated by geotechnical measures with ecological measures as supplements, and taking mountain small watersheds as the basic unit, we construct a comprehensive disaster reduction model based on the coupling of slope stabilization and energy dissipation through ecological engineering and geotechnical engineering synergy. This forms a cross-scale ecological-geotechnical collaborative disaster reduction system at "slope-gully-watershed" scales [Figure 4: see original paper]. At the slope scale, main technologies and models include buffer and energy dissipation protection technology based on plant and artificial structure combinations, slope rill erosion protection technology based on tree root soil reinforcement, and optimized technology for slope stabilization with anti-slide piles/trees, effectively controlling slope material sources entering gullies and achieving slope protection and sediment reduction. At the gully scale, an ecological-geotechnical collaborative disaster reduction configuration mode is formed, combining upstream geotechnical retention projects, midstream step-pool structure energy dissipation systems, and downstream vegetation filter strips as biological engineering, reducing gully erosion and incision and achieving stepwise regulation and energy dissipation. At the watershed scale, with the goal of suppressing the index effect of solid material sources in disaster formation areas, guided by stepwise regulation of materials and energy in flow areas, and based on principles of balanced sediment transport and deposition in accumulation areas, an ecological-geotechnical collaborative disaster reduction system is integrated across different processes of "formation-movement-accumulation," achieving comprehensive ecological-geotechnical engineering prevention and control of disaster-causing risks in small watersheds.

### 3.3. Key Technologies and Models for Comprehensive Risk Management

Disaster risk comprehensive management is a crucial non-engineering measure in disaster prevention and mitigation, which together with the aforementioned green disaster reduction engineering constitutes the integrated disaster reduction system. It is particularly critical for ensuring sustainable economic and social development and promoting green development in mountain areas. Communities are the most basic social units participating in disaster prevention, mitigation, and relief. Starting from organizational management capacity building, resident awareness enhancement, safety technology guarantee, infrastructure improvement, and housing safety fortification, we can construct a safe community operation management model and promote safe community construction [Figure 5: see original paper]. First, organizational management capacity building includes systems and mechanisms, emergency teams, emergency plans, and material reserves. Second, resident awareness enhancement includes disaster prevention and mitigation education training and emergency drills. Third, safety guarantee technologies mainly include emergency evacuation route design and shelter planning, disaster warning sign layout, key medical rescue technologies, and virtual reality (VR) technology applications for simulating disaster scenarios. Fourth, infrastructure improvement mainly includes road upgrading and maintenance, emergency shelter construction, community protection forest projects, and medical rescue station construction. Fifth, housing safety fortification mainly includes exterior wall protection projects and indoor safety projects.

### 3.4. Key Technologies and Models for Green Industrial Development

Breaking through traditional administrative boundaries and taking small watersheds as the basic unit, we explore pathways and models for green industrial development in mountain areas based on three-dimensional terrain characteristics, from industrial spatial layout, industrial type selection, and key technology research and development for protection and development [Figure 6: see original paper]. Industrial layout in each region requires scientific diagnosis of suitable scope and degree for territorial spatial development and utilization, with key points being the co-construction of disaster reduction and industrial infrastructure and pursuing integrated industrial development. First, river valley areas have the best natural endowments for developing characteristic industries but are also the most severely and directly affected by various mountain disasters. Key research focuses on key technologies and models for restoration and sustainable utilization of disaster-destroyed sites represented by debris flow beaches and alluvial fans, including land consolidation and protection technology organically combined with green disaster reduction engineering, soil remediation technology, topsoil water retention technology, and fertilizer conservation technology, to develop green and efficient modern agricultural industries with regional characteristics such as grain-cash crop composite industries, flower industries, and green aquaculture industries. Second, mid-slope areas are formation and flow areas for various mountain disasters and also the main distribution areas for terraced fields. Implementing protection and development simultaneously in these areas is particularly critical. We recommend relying on land consolidation projects such as "slope-to-terrace" conversion, advocating comprehensive technical systems for contour farming, focusing on developing economic forest and fruit crops with strong soil consolidation and slope protection functions, moderately developing captive breeding industries, and exploring green planting-breeding circular agricultural models represented by "pig-biogas-fruit," "fruit-grass-livestock," and "fruit-medicine-poultry." For mountain areas with medium to high risk of forest fires, a series of small pond and reservoir systems can also be reasonably located within gully systems in mid-slope areas to achieve multiple functions including fire prevention, irrigation, and disaster reduction. Third, high mountain areas are the main material source areas for debris flow disasters, have critical water conservation functions, and are also excellent locations for developing ecological breeding and understory economies. We recommend developing moderately scaled green breeding industries and economic forest and fruit industries, researching key technologies for high mountain ecological protection and restoration, and building them into key ecological barriers ensuring whole-watershed safety.

## 4. Demonstration of the Synergy Model for Disaster Risk Reduction and Industrial Development

### 4.1. Overview of the Demonstration Zone

Under the Strategic Priority Research Program (Class A) of Chinese Academy of Sciences titled "Beautiful China: Science and Technology Engineering for Ecological Civilization Construction,"the project "Key Technologies and Demonstration for Green Regulation of Mountain Disaster Risk Under Climate Change" selected the Reshui River basin in Hongmo Town, Xide County, Liangshan Yi Autonomous Prefecture, Sichuan Province as a demonstration zone. Through comprehensive investigation of the current status, problems, and needs of disaster prevention and mitigation and economic and social development in the watershed, we compiled the *Planning Scheme for the Demonstration Zone of Synergy Between Disaster Risk Reduction and Green Development in Reshui River Basin, Hongmo Town, Xide County, Liangshan Prefecture (2020–2035)*. We developed a series of ecological-geotechnical green disaster reduction engineering technologies, safe community engineering technologies, and green industrial technologies and models, all of which were applied in the demonstration zone, aiming to build it into China's first demonstration zone with high social influence for synergy between disaster risk reduction and characteristic industrial development.

Reshui River is a first-order tributary on the left bank of the Anning River, with a main channel length of 28.08 km, average longitudinal gradient of 67‰, and watershed area of 163.22 km$^2$. It features a low-to-medium mountain landform type with overall topography high in the northeast and low in the southwest [Figure 7a: see original paper]. The watershed has developed 19 branch gullies with very active debris flows occurring annually at different scales, making it a typical high-frequency debris flow gully that seriously damages livelihood safety and infrastructure [Figure 8: see original paper]. The watershed is mainly located in Hongmo Town, Xide County, with jurisdiction over 9 administrative villages, totaling over 2,470 households and 9,950 people, predominantly Yi ethnic group, representing a typical Han-Yi ethnic integration area. Land use types are dominated by forestland, grassland, and cultivated land, accounting for 52.31%, 22.06%, and 20.70% respectively [Figure 7b: see original paper], with traditional agriculture as the main industry.

### 4.2. Demonstration Objectives

By collaboratively implementing ecological-geotechnical disaster reduction projects, green industrial projects, and safe community projects in the Reshui River watershed, we aim to achieve multi-objective optimization of disaster reduction benefits, economic and social benefits, and ecological environmental benefits. First, disaster reduction benefit objectives include reducing disaster scale by 30%, reducing disaster losses by over 50%, reducing high-risk areas by 40%, extending the effective period of engineering disaster reduction measures by over 50%, and ensuring the safety of life and property for over 10,000 people inside and outside the watershed. Second, economic and social benefit objectives include adding 100 million yuan in economic benefits, increasing local residents' income by 1–2 times, and providing disaster prevention and mitigation education and training benefits to over 7,000 people. Third, ecological environmental benefit objectives include increasing vegetation coverage by 20%, improving ecological environmental functions by over 30%, and significantly enhancing the overall ecological environmental quality of the small watershed.

### 4.3. Demonstration Content

**(1) Compiling the planning scheme for the demonstration zone of synergy between disaster risk reduction and green development.** Clarifying the coordinated and interactive relationships among "disaster–environment–human" elements in the demonstration zone, we developed a small watershed comprehensive disaster risk reduction and industrial development collaborative planning scheme based on small watershed disaster risk assessment technology and suitability evaluation and optimization technology for territorial "production-living-ecological space."This systematically addresses synergy issues between disaster reduction and development in medium- and high-risk mountain areas. Based on the above technical system, we conducted comprehensive planning for the entire Reshui River watershed from seven aspects: geological disaster management projects, monitoring and early warning projects, land consolidation projects, green industrial projects, safe community projects, beautiful rural demonstration, and institutional mechanism construction, compiling the *Planning Scheme for the Demonstration Zone of Synergy Between Disaster Risk Reduction and Green Development in Reshui River Basin, Xide County* [Figure 9: see original paper]. This planning scheme passed expert review by multiple departments of Xide County People' s Government in September 2021, with core technologies and content incorporated into the *Implementation Plan for the Ecological Restoration Project of Mountains-Waters-Forests-Farmlands-Lakes-Grasslands in Anning River Basin* and the *Comprehensive Land Consolidation Planning of Anning River Basin in Sichuan Province (2022–2035)*, leading ecological civilization construction in the Anning River Basin.

**(2) Demonstration projects for ecological-geotechnical collaborative disaster reduction.** Based on comprehensive investigation and evaluation of disaster hazards in 19 branch gullies throughout the Reshui River watershed, we selected Fenchagou and Yuergou—representing the highest disaster risk and most difficult treatment challenges on the left and right banks—for green disaster reduction engineering demonstration. First, Fenchagou (1.13 $km^2$): Focusing on its watershed characteristics, we conducted experimental demonstration of ecological-geotechnical optimized configuration disaster reduction combining "step-pool energy dissipation system + ecological slope protection + protective forest combination." Demonstration technologies included optimized technology for reinforcing slopes with trees at the rear edge of landslides in the upstream area, optimized configuration technology for 21 step-pool energy dissipation structures combined with gully protective forests in the midstream and downstream areas, optimized configuration technology for tree-shrub-grass ecological protection in gullies, and S-shaped plant dam optimized configuration models [Figure 10a: see original paper]. Second, Yuergou (9.20 $km^2$): Adopting a treatment approach of "source water blocking + regulation and storage for energy dissipation + slope protection for sediment reduction + regulated flow guidance," we conducted experimental demonstration of ecological-geotechnical collaborative disaster reduction combining "biological check dams + permeable retention structures + asymmetric drainage"[Figure 10b: see original paper]. Additionally, we guided the implementation of land consolidation and river channel management projects, effectively dredging the main Reshui River channel and adding over 780 mu of high-quality cultivated land.

**(3) Green industry demonstration projects.** Addressing the prominent problems of widespread distribution and difficult utilization of disaster-destroyed sites (debris flow beaches and alluvial fans) in the watershed, which cause serious soil erosion and landscape damage, we focused on conducting experimental demonstrations of key technologies for improvement and sustainable utilization of debris flow beaches, green and efficient aquaculture on debris flow beaches, and "fruit-grass-poultry" composite agricultural models on debris flow alluvial fans [Figure 11: see original paper]. First, debris flow beach improvement and sustainable utilization demonstration: By deploying various soil introduction models combined with flood irrigation for siltation, we systematically solved soil cultivation problems on beaches; researched plant root water regulation technology and efficient water-saving irrigation technology combined with groundwater level experiments to solve water retention problems; and through trial planting of various economic crops and flood-tolerant crops such as mulberry, crisp plum, Orah mandarin, fig, and honeysuckle, enhanced the ecological and economic benefits of debris flow beaches. Second, green and efficient aquaculture demonstration on debris flow beaches: By scientifically selecting aquaculture base locations in coordination with upstream Fenchagou disaster treatment projects, combining "fish + rice (vegetable)" symbiotic technology and ecological treatment technology for aquaculture tail water, we solved safety and pollution control challenges; developed tail water recycling systems to ensure water sources for aquaculture bases; introduced solar clean energy and created "specialty aquatic products + ecological tourism" agricultural models to ensure green and high-quality development of aquaculture. Third, "fruit-grass-poultry" composite agricultural model demonstration on debris flow alluvial fans: By deploying various "fruit-grass" intercropping models to promote upstream ecological conservation, researching intelligent mobile chicken coops and green breeding technology to improve disaster avoidance capacity and production efficiency, and innovating micro-farm management mechanisms, we achieved full-process integration of disaster reduction and green development.

**(4) Safe community demonstration projects.** Based on disaster case analysis and field investigation of community status, we identified key links and bottlenecks in community risk management, researched key disaster risk management technologies, conducted disaster risk education, training, and drills, and thereby constructed a safe community construction model. Key technologies researched and developed include: designing unique disaster identification signs with Liangshan characteristics by integrating Yi ethnic cultural elements; developing a "disaster smart signage interactive guidance system" integrating disaster science popularization and emergency evacuation guidance; developing mountain disaster education and training VR scenarios and a "Safety Circle" application (APP) based on Huawei Mobile Services (HMS) ecosystem; and exploring new approaches to disaster prevention and mitigation education and safety training through developing characteristic courses, compiling mountain disaster risk education and training manuals, and conducting characteristic skills training and emergency drills. These key technologies were demonstrated and applied in Taoyuan Village, the core community in the Reshui River watershed, significantly enhancing local residents' awareness and capacity for proactive disaster prevention and mitigation. The integrated safe community construction technology helped Taoyuan Village successfully apply for designation as a National Comprehensive Disaster Reduction Demonstration Community.

**(5) Institutional mechanism construction.** Based on international disaster prevention and mitigation trends and China' s latest strategic deployments, combined with the current status of mountain disaster risk management in the demonstration zone, we constructed a multi-level, whole-process, multi-stakeholder mountain disaster risk management mechanism, researched diversified disaster risk transfer models, and reached a disaster insurance cooperation intention with China Reinsurance's Catastrophe Risk Management Co., Ltd. We focused on constructing a mountain disaster risk management mechanism with Taoyuan Village as the core foundation, coordinated guidance from Xide County and Hongmo Town, and participation from enterprises and institutions. Focusing on the concerns of communities, towns, counties, and enterprises, we elaborated the main contents and key pathways for multi-stakeholder participation in mountain disaster risk management from three stages: pre-disaster, during disaster, and post-disaster [Figure 12: see original paper]. The institutional mechanism construction practice in the demonstration zone helps achieve diversified participation, diverse participation methods, and enhanced participation levels and capabilities in community disaster risk management, realizing the organic combination of "top-down" and "bottom-up" risk management and effectively promoting local disaster reduction and green development synergy.

### 4.4. Demonstration Achievements

Through comprehensive planning for synergy between disaster risk reduction and characteristic industrial development in the Reshui River watershed and focused implementation of multiple demonstration projects, the project team has significantly changed the lagging economic and social development situation in the demonstration zone and well achieved the expected objectives. First, implementing ecological-geotechnical collaborative disaster reduction demonstration projects in key branch gullies, combined with riverbank treatment projects, formed a comprehensive disaster reduction system that protects over 1,000 mu of cultivated land and the life and property safety of over 10,000 people in the midstream wide valley area, greatly reducing disaster risk. Second, guiding land consolidation projects added 780 mu of cultivated land and created 1,270 mu of new high-standard basic farmland; coordinating with local governments and enterprises to implement six demonstration projects with total investment exceeding 100 million yuan. Third, researching and developing a series of key technologies and models for improvement and sustainable utilization of debris flow disaster-destroyed sites achieved resource utilization of disaster-destroyed sites, demonstrating effectiveness in boosting farmers' income and promoting local employment. Fourth, researching and developing a series of key disaster risk management technologies, adding multiple software and hardware infrastructure facilities, and conducting disaster prevention and mitigation education, training, and drill activities based on VR significantly enhanced grassroots government disaster risk management levels and community residents' disaster risk awareness and response capabilities, directly benefiting over 8,000 people. The comprehensive demonstration zone construction project was officially designated as a premium land consolidation project in the Anning River Basin, the demonstration community Taoyuan Village successfully applied for designation as a National Comprehensive Disaster Reduction Demonstration Community, and the synergy concept of disaster reduction and green development was formally incorporated into the *Implementation Plan for the Ecological Restoration Project of Mountains-Waters-Forests-Farmlands-Lakes-Grasslands in Anning River Basin* and the *Comprehensive Land Consolidation Planning of Anning River Basin in Sichuan Province (2022–2035)*, ensuring that demonstration achievements can "stay and spread." The demonstration zone construction achievements have been featured in special reports by Xinhua News Agency, *Sichuan Daily*, and *Science and Technology Daily*, and reprinted by mainstream media, achieving prominent social impact.

## 5. Promotion of the Synergy Model for Disaster Risk Reduction and Industrial Development

### 5.1. Analysis of Necessity and Feasibility for Promotion

**(1) Urgent need to consolidate poverty alleviation achievements and help vast mountain areas achieve modernization in sync.** Although China completed the poverty reduction target of the UN 2030 Agenda for Sustainable Development 10 years ahead of schedule, creating a miracle in world poverty reduction history, the task of preventing large-scale returns to poverty remains arduous. Due to limitations of natural conditions and relatively weak development foundations, obvious gaps still exist between mountain areas and plain areas. Solving the synergy problem between disaster reduction and development, exploring a Chinese-style modernization path for mountain areas, and achieving socialist modernization in sync with the rest of the country represent the aspirations of 330 million mountain residents. This is also a strategic initiative of global significance that addresses China' s unbalanced and insufficient development and resolves contemporary major social contradictions, holding important leading and demonstration value for global mountain development.

**(2) Objective need to implement the concept of overall development and security and improve grassroots governance capabilities.** Ensuring safety and promoting development are two important long-term tasks for China' s sustainable economic and social development. President Xi Jinping has attached great importance to overall development and security, publishing a series of important discourses on the dialectical unity between development and security. The long-standing problems of non-benign coupling between disasters and poverty and lack of coordination between disaster reduction and development in China' s mountain areas essentially reflect fragmented management and insufficient comprehensive governance capabilities among government departments. In the new journey of rural revitalization, there is an urgent need to innovate the synergy model for mountain disaster risk reduction and industrial development, using new concepts and models to coordinate disaster reduction and green development, truly achieving both harm elimination and benefit creation.

**(3) Multiple major strategic initiatives being implemented in vast mountain areas create realistic conditions for promoting the synergy model.** Under the main theme of building a Beautiful China, practicing the "Two Mountains" theory and promoting high-quality development are becoming key measures for green leapfrog development in mountain areas. The rural revitalization strategy prioritizes industrial prosperity and ecological livability as its first two of five general requirements, objectively providing broad prospects for coordinating disaster reduction and development in disaster-prone mountain areas. Various planning schemes and demonstration village construction projects being implemented in mountain areas, such as territorial spatial planning, rural revitalization planning, and village planning, all create realistic conditions for rooting the synergy concept and model of disaster risk reduction and industrial development.

### 5.2. Recommendations for Promoting the Synergy Model

The synergy model for integrated disaster risk reduction and industrial development breaks through administrative boundaries and emphasizes multi-stakeholder participation and cross-departmental coordination. However, due to potentially large differences in natural disaster characteristics and characteristic industrial development conditions across regions, the synergy model exhibits obvious regional features. Therefore, we recommend promoting this synergy model in an orderly manner by region, level, and batch, following the general principle of moving from points to surfaces and then fully 铺开. Specifically, we can refer to China' s first-level flash flood zoning results and conduct pilot promotion within nine major regions across the country' s mountainous and hilly areas. During the promotion process, we recommend focusing on four aspects of work. First, select optimal models: systematically review and summarize existing synergy models for disaster reduction and development in each region, scientifically evaluate their comprehensive benefits of "disaster reduction–social–economic–ecological" aspects, select optimal models, identify their shortcomings and improvement strategies based on the new green synergy theory, and clarify their applicable conditions and suitable promotion scope. Second, compile planning schemes: deeply integrate the synergy concept of disaster reduction and green development into various planning schemes; for regions where main planning schemes have been completed, we recommend supplementing with planning schemes for disaster reduction and green development synergy demonstration zones. Third, create demonstration models: relying on various demonstration village construction projects, integrate and apply various synergy technologies and models for disaster risk reduction and industrial development to build demonstration models and promote application and promotion. Fourth, consolidate institutional guarantees: construct a green development collaboration mechanism to form institutional guarantees. Improve multi-level government linkage management and coordination mechanisms at provincial, municipal, county, town, and community levels, and build cross-departmental green development collaboration mechanisms that coordinate development and reform, emergency management, natural resources, agriculture and rural affairs, forestry and grassland, water resources, and other departments. This would enable unified leadership, unified deployment, and coordinated work on disaster risk prevention and control, characteristic industrial development, ecological civilization construction, and rural revitalization projects, changing the past "nine dragons governing water" situation, focusing on one blueprint, pooling multi-party resources, concentrating efforts, and achieving long-term success to form a scientific and efficient green development guarantee mechanism.

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*Note: Figure translations are in progress. See original paper for figures.*