



# Rural vulnerability, migration, and relocation in mountain areas of Western China: An overview of key issues and policy interventions

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## ABSTRACT

Western China features a vast area of mountains and high plateaus where millions of people, including diverse ethnic minority groups, have inhabited for generations. Geographically located in the mountainous, remote, and isolated regions, rural communities are prone to natural hazards and thus become vulnerable to impoverishment. To reduce rural vulnerability, many people residing in mountainous villages opted to out-migrate from their original villages and hometowns while some took in-situ adaptation measures. A host of government-sponsored resettlement programs have been carried out to help rural villagers seek alternative livelihoods elsewhere over the past four decades. To achieve a sustainable future for rural communities in mountainous areas of western China, more effective policies and measures need to be developed and enforced.

## 1. Introduction

China is a country with mountainous areas accounting for 52% of its total land area. About 18% of the total population resides in mountainous regions (Huddleston et al., 2003). Mountains and plateaus dominate the landscape of western China. Despite unprecedented economic growth in China over the past 40 years, many mountainous areas in western China have been left behind, resulting in the out-migration of millions of rural farmers and ubiquitous depopulation from such communities. This out-migration has led to drastic demographic and social transitions in mountainous areas. This paper addresses two questions. First, why did many people migrate away from their hometowns in western China, and was the migration or resettlement process related to a rural vulnerability in mountainous communities? Second, is it possible to create a more sustainable future for mountainous communities?

This study aims to provide an overview of rural vulnerability in western mountainous communities and examine the mechanisms for out-migration and government-sponsored resettlement that have been practiced as coping strategies for rural vulnerability. The rest of the paper is structured into three sections. Section 2 briefly discusses the concepts of vulnerability and rural vulnerability and their application to the context of rural mountainous communities based on our pro-

posed analytic framework. Section 3 reviews rural migration and the patterns of resettlement in western mountainous areas. Section 4 concludes the paper with a discussion of policy issues.

## 2. Vulnerability

### 2.1. Defining 'vulnerability' and 'rural vulnerability'

*Vulnerability* refers to the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards (UNDRR, 2017). It has been studied extensively in multiple disciplines, including economics, sociology, anthropology, environmental science, geography, public health, psychology, human ecology, disaster management, and climate change (Alwang et al., 2001; Birkmann, 2006; Cutter et al., 2003; Villagran de Leon, 2006; Weichselgartner, 2001). Vulnerability is a product of exposure, sensitivity, and adaptive capacity (Adger, 2006). *Exposure* measures the degree to which a system experiences stress or shocks. *Sensitivity* refers to the degree to which a system is modified or affected by perturbations. *Adaptive capacity* is the ability of a system to absorb or cope with the effects of stressors (Eakin and Luers, 2006). Thus vulnerability involves two facets of a system: its intrinsic proper-

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ties and its extrinsic features. The former includes sensitivity, resilience, coping, and adaptive capacity, while the latter refers to its exposure to stress, shocks, and other external conditions and environments (e.g., relief measures and external interventions) (Turner et al., 2003).

*Social vulnerability* refers to the inability of people, organizations, and societies to cope with adverse impacts from multiple stressors to which people are exposed. It is influenced by multiple socio-demographic characteristics: gender, age, health status and disability, ethnicity, race, nationality, caste or religion, socioeconomic status, and institutional aspects (Birkmann et al., 2006, Hilhorst and Bankoff, 2004, Wisner et al., 2004). *Rural vulnerability* is defined as being subject to specific circumstances found in rural environments (Aleksandrova et al., 2014; Leichenko and O'Brien, 2002; Saldana–Zorrilla, 2008). In this study, rural vulnerability is a place-based concept that encompasses both biophysical and social aspects of vulnerabilities of rural communities in the mountainous regions.

According to the hazards-of-place model of vulnerability (Cutter, 1996), various elements that constitute rural vulnerability in mountainous areas interact to produce the vulnerability of specific places and people who live there. Biophysical vulnerability originating from a mountainous geographical context includes eco-environmental fragility, susceptibility, and irreversibility, while social vulnerability concerns such elements as remoteness, marginality, and impoverishment. Due to these aspects of rural vulnerability, mountain communities tend to face more frequent and intense risks. As a means of coping with the extensive risks and challenges, population mobility (including migration, relocation, displacement and resettlement) is deployed as an adaptive approach for risk management. Based on the hazards-of-place vulnerability model, we constructed an analytic framework for understanding rural vulnerability and human mobility in mountainous regions (Fig.1).

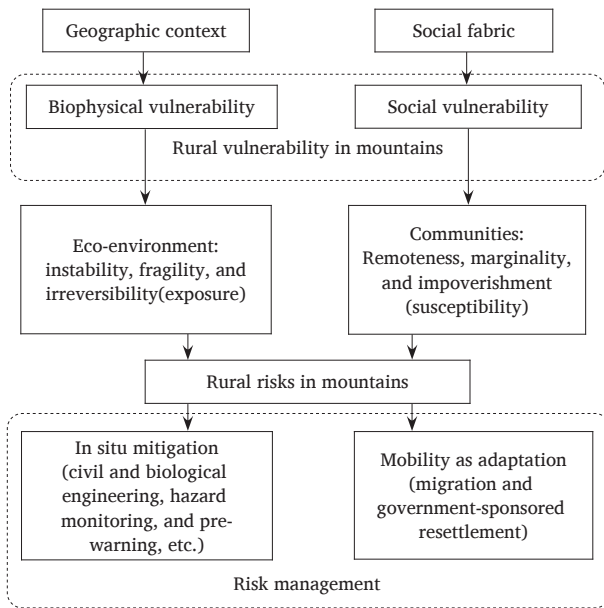


Fig. 1. Analytic framework for rural vulnerability and human mobility in mountainous regions

## 2.2. Rural vulnerability in mountainous areas of western China

### 2.2.1. Fragile environments and impact from climate change

Mountain environments are fragile and sensitive to disruptions. Any perturbation may result in cascading reactions in mountainous areas and adverse effects on mountain inhabitants and their communities. Characterized by susceptibility and instability, fragile eco-

environment has low resilience to stress and shocks. Fragile eco-environments in China are mainly distributed in western mountainous regions. Zhao (1999) identified seven fragile ecological zones (FEZ):1) *semi-arid and semi-humid areas* in northern China, 2) *semi-arid areas* in northwestern China, 3) *lime-rock mountainous areas* in southwestern China, 4) *arid and steep valleys* in southwestern China, 5) the *Qinghai-Tibetan Plateau*, 6) *plain areas* in northern China, and 7) *hilly areas* in southern China. Except for the plain areas in northern and hilly areas in southern China, five FEZs are located in western China, especially in mountainous regions and high plateaus.

Due to harsh climatic conditions such as excessive precipitation in some areas, low temperatures, aridity, and high solar radiation, mountainous areas are prone to natural hazards (e.g., flash floods, landslides, and debris flow) and severe land degradation. Once damaged, mountain ecosystems may suffer irreversible degradation or take an exceedingly long time to regenerate (Jansky et al., 2002). Soil erosion, land desertification, glacial retreat, reduced biodiversity, rangeland degradation, and aggravated natural disasters are typical environmental problems in western mountainous areas (Shi and Li, 1999). These environmental problems impose a tremendous threat to human life, farmers' livelihoods, and the sustainability of natural resources in mountain communities, affecting local people's social, economic, and cultural activities; hence, the environmental problems lead to increased social vulnerability for mountain dwellers.

Apart from eco-environmental fragility, mountainous areas in western China face challenges emanating from global climate change. Existing studies show mountainous regions worldwide are experiencing apparent warming and enduring enormous climate impacts (Adler et al., 2019, Ingty, 2017; Palomo, 2017). Evidence indicates the average temperature on the Tibetan Plateau has increased by 0.2–0.6 °C per decade over the past 50 years, a much more significant change than that in some lowland areas (Brodnig and Prasad, 2010). Mountainous areas have also experienced droughts and water scarcity (McDowell et al., 2013). The retreat of glaciers may trigger landslides, soil erosion, and an outburst of flooding (Orlove, 2009). The degradation of permafrost affects snow evolution and hydrological cycles in high mountains, which, in turn, adversely impacts alpine ecosystems and mountain environments (Watson and Haeberli, 2004). Overall, climate variability and change in mountainous regions have profound social, economic, cultural, and religious implications (Wang and Cao, 2015).

Adapting to environmental change includes changes to people's livelihood activities related to forestry, grazing, horticulture, and tourism in mountainous areas. Environmental changes also affect the regeneration of some natural resources, such as medicinal herbs that comprise an important livelihood resource for mountain residents (Gentle and Maraseni, 2012; Xu et al., 2009). The urbanization rate remains low in western mountain areas of China, but a significant proportion of the population still engages in subsistence farming activities, which are primarily dependent on climatic conditions. Studies have shown that farmers are likely to face higher risks to their livelihood than others due to climate change (Wang and Cao, 2015; Zheng and Byg, 2014).

### 2.2.2. Exposure to mountain hazards

Mountain communities are exposed to multiple natural hazards: earthquakes, landslides, debris flows, flash floods, snowstorms, and the like (Hewitt, 1992, Renaud and Jansky, 2008). As mountains are often located in tectonic intersections and seismic belts, mountain inhabitants suffer exceptional damages and losses from earthquakes (Halvorson and Hamilton, 2007; Hewitt, 1984). In China, the majority of recent earthquakes have occurred in the western regions, where active seismic faults remain aligned with mountain ranges, forming a range of seismic zones. Records show that China was hit by 125 earthquakes (measured at magnitudes on the Richter scale of 5 or above) during 2008–2017, and over three-quarters of them occurred in the

western region (Table 1). The most destructive strikes, namely the Wenchuan earthquake in 2008, the Yushu earthquake in 2010, and the Lushan earthquake in 2013, were all distributed along mountains

or high plateaus in western China. Thus rural communities disproportionately suffered casualties and economic loss (Wang, 2012).

**Table 1**  
Disastrous earthquakes in western China in 2008–2017, by province

Region/province	Total No.	No. of earth-quakes on the Richter scale $\geq 5$	Casualties	Deaths	Direct economic loss (million RMB)
China	143	116	1295725	73095	1126510
Western China	125	111	1295512	73087	1095757
Sichuan	16	13	486963	69500	938689
Qinghai	9	9	13711	2698	25384
Yunnan	29	26	176941	737	69536
Gansu	6	4	2513	95	24504
Tibet	9	9	229230	37	15114
Xinjiang	45	44	288107	12	20816
Guizhou	2	1	75020	6	517
Chongqing	5	1	14	2	77
Inner Mongolia	3	3	23013	0	1016
Guangxi	1	1	0	0	102
Shaanxi	1	0	0	0	0
Ningxia	0	0	0	0	0

Sources: *China Environment Statistical Yearbook 2009–2018*

Mountain communities are more frequently exposed to other geo-hazards. Landslides, debris flows, landfalls, and ground subsidence are common in vast swathes of the western mountain regions. Statistics show that from 2008 to 2017, the death toll due to geo-hazards in western China was over 4,000, accounting for nearly 80% of all fa-

talities in China during that period (Table 2). Geo-hazards are mainly distributed in the mountain ranges of Hengduan and Qinling on the southeastern fringe of the Tibetan Plateau, including the provinces of Yunnan, Sichuan, Gansu, Shaanxi, and the Tibetan Autonomous Region.

**Table 2**  
Geological disasters in western China in 2008–2017

Region /province	Total	Land-slides	Land falls	Debris flows	Ground subsidence	Casualties	Deaths	Direct economic loss(million RMB)
China	151493	95449	37566	10199	3423	10038	5527	47688
Western China	57281	27651	17784	6114	1321	8091	4366	32068
Chongqing	5050	3913	890	115	115	390	187	3242
Sichuan	18805	10466	5269	2587	102	1395	582	8477
Guizhou	2963	2078	559	56	140	588	333	1616
Yunnan	5588	3747	818	776	100	1242	520	4758
Tibet	1789	314	590	866	19	124	93	1200
Shaanxi	3417	1986	919	324	122	749	377	2055
Gansu	13044	2540	5870	939	95	2638	1795	8500
Qinghai	242	159	60	29	1	62	27	73
Ningxia	88	31	38	5	5	0	0	33
Xinjiang	606	235	61	294	11	119	94	1490
Guangxi	5562	2165	2693	86	559	762	342	521
Inner Mongolia	127	17	17	37	52	22	16	99

Source: *China Environment Statistical Yearbook 2009–2018*

Human activities play a crucial role in many so-called "natural disasters" induced by geological and hydro-meteorological drivers. Such activities are driven either by internal factors—such as deforestation, slope cultivation, house and road construction, water diversion—or external factors—such as dam construction, commercial mining and logging, and tourism development (Fig. 2).

Natural hazards have repercussions for mountain communities.

Farming activities primarily rely on climatic and weather conditions, and climate variability and extreme weather events can lead to drastic change and losses in agricultural production. Geo-hazards directly damage houses, destroy livelihoods and thrust farmers/herders into acute poverty. Natural disasters have myriad social ramifications as well: destroying infrastructure, disrupting social services, and interrupting social networks.

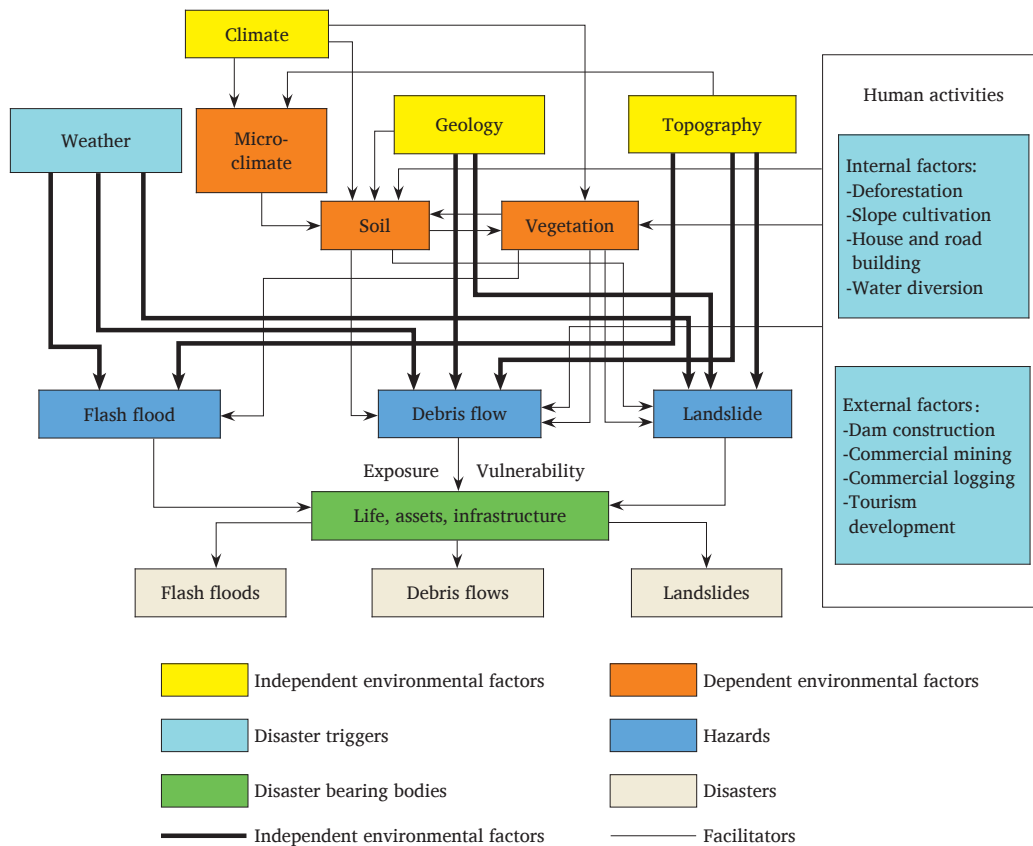


Fig. 2. Mechanisms for natural disasters in mountainous areas (Chen et al., 2013)

2.2.3. Vulnerability to poverty in mountain communities

As a critical indicator of rural vulnerability in mountainous areas, poverty no longer only implies lack of people's basic needs. It has been generally recognized that the traditional concept of poverty is insufficient, as it cannot reflect the dynamic features of impoverishment. Therefore, the concept of vulnerability, as a major indicator of poverty, was proposed and widely used in development literature. Assessing vulnerability is particularly helpful for analyzing poverty in mountain areas.

Mountain communities and households with high vulnerability tend to be susceptible to impoverishment. Those poverty-stricken communities and disadvantaged households are often concentrated in fragile environments. China achieved remarkable progress in poverty alleviation over the past four decades, with hundreds of millions of rural people lifted out of poverty. Poverty is now sporadic in the eastern but not entirely eradicated in the western mountain regions (Zhou and Xiong, 2018). In the mid-1980s, when China launched its first batch of anti-poverty programs, 11 out of 18 identified poverty-stricken regions were in western China<sup>①</sup>. In 1994, the country began implementing its “8/7 Anti-poverty Plan”, which aimed to lift 80 million people out of poverty in 7 years (by the year 2000). In this plan, 592 of the nation's counties were identified as poverty-stricken<sup>②</sup>, 383 of which were distributed in the western region and many were in mountainous areas.

In 2010, 26.88 million rural people lived under the national poverty line (i.e., per capita annual net income of RMB 1,196), and two-thirds (or 17.51 million) of them lived in western China (Liu and Wuzhati, 2013). The poverty rate in the western region (8.3%) was much higher than the national average level (2.8%) in 2010. In 2011, China

issued the “Guidelines for Rural Poverty-Alleviation and Development (2011–2020)”. Nine out of the total 14 major poverty-stricken regions were located in the western region. Except for three prefectures in southern Xinjiang Uygur Autonomous Region, all the other major poverty-stricken regions were distributed in mountainous areas (including Liupan, Qin-Ba, Wuling, Wumeng, Dian-Gui-Qian Karst Area, Western Yunnan Border Area, Tibet, and Tibetan areas in the provinces of Yunnan, Sichuan, Gansu, and Qinghai). Nearly two-thirds of the 680 poverty-stricken counties designated by the State Council were located in the mountainous areas of western China in 2012. In 2016, the State Council issued the “National Plan for Targeted Poverty Alleviation in the Thirteenth Five Years (2016–2020)”, aiming to lift 56.3 million people registered under the national poverty line out of poverty by the end of 2020. In this plan, 128,000 villages and 832 counties were categorized as registered poverty-stricken villages and counties. Geographically, most of them are located in the mountainous and hilly regions of western China. A recent study notes that China has 1651 mountainous and hilly counties, making up 57.5% of all counties, and approximately 90% of all poverty-stricken people are from mountainous regions (Deng et al., 2018).

3. Rural migration and resettlement in China's mountainous areas

Rural vulnerability gives rise to rural risks as mountain communities are exposed to a litany of stressors and shocks. To mitigate their adverse impacts various plans and programs were initiated in mountainous regions in the past decades. Apart from in situ mitigation measures (e.g., civil and biological engineering, hazard monitoring and

①The western region of China encompasses 12 provinces (municipalities or autonomous regions). The term is not the same as it was when used before the program was initiated in early 2000; at that time “western region” included only 10 provinces (municipalities or autonomous regions).

②In addition to counties designated as poverty-stricken at the national level, additional counties are designated as poverty-stricken at the provincial level.

pre-warning, soil conservation, and water diversion projects), migration and resettlement have been chosen by many people and local government departments that are accountable for the safety of the population in mountainous areas.

### 3.1. Migration: a major adaptive strategy to cope with risks and challenges

Along with economic development, vast numbers of rural people have moved from mountains to lowlands and plains and from western provinces to eastern coastal regions. Such migration flows have resulted in depopulation and spatial redistribution of population in mountainous areas (Chen et al., 2010). Studies show a myriad of factors contributed to the exodus of rural people from mountain areas. Among the “pull factors” of destination areas are some significant socioeconomic factors: potential employment opportunities and higher incomes in cities, better living conditions, convenient transport and telecommunication networks, more career opportunities, and better education for offspring compared to the mountainous regions (Kang et al., 2016).

Before de-collectivization in the early 1980s, millions of surplus labor accumulated in the countryside due to rapid population growth and stringent institutional and policy constraints that were in place from late 1950s to the 1970s. In the early 1980s, the establishment of the household responsibility system for agricultural production and the relaxation of the household registration (*hukou*) system released tens of millions of rural laborers from agricultural production, prompting their migration to cities and towns (particularly in coastal regions where export-oriented industries boomed). The mountain communities were no exception.

Labor migration has mixed effects on mountain communities. Remittances, new knowledge, information, and skills that migrants have sent or brought back can boost agricultural production and social progress in their hometowns. Labor migration facilitates poverty reduction (Du et al., 2005; Zhu and Luo, 2010). Out-migration is conducive to environmental regeneration and restoration of degraded ecosystems (Qin, 2010). However, it is undeniable that out-migration negatively impacts rural communities, causing shortages of labor for farm activities and provision of social services and the construction of public works, land abandonment, and a deficit of caregivers for the aged people and young children left behind (Pan and Wang, 2018). Due to out-migration and drastic declines in school-age populations, village schools in some remote mountain areas have been closed or amalgamated. Income from farm activities becomes insignificant. Many farmers move to towns and cities, abandoning their farmland, seeking off-farm jobs or taking care of school-aged children as their main activities (Liu and Xing, 2016).

### 3.2. Government-sponsored resettlement: an approach to achieving various targets

#### 3.2.1. Environmental resettlement in ecologically fragile environments

China has achieved unprecedented economic progress since the end of the 1970s, but development remains unbalanced across regions. As a remedy, the Chinese government initiated the “Go West” policy in 2000. Boosting environmental reconstruction and curbing environmental deterioration was designated as a fundamental goal. A significant strategy employed to achieve this objective was the relocation of people away from ecologically fragile environments in the hope of reversing environmental degradation (Yang et al., 2020). Moreover, many people who have inhabited remote mountains, frigid highlands, and arid rangelands can barely live a basic life due to the constraints of the adverse living environments. These people may become better off in more inhabitable conditions after resettlement. This type of relocation, termed “ecological migration” in the Chinese context, was initially implemented on the Tibetan plateau and Inner

Mongolian Steppes (Dickinson and Webber, 2007; Rogers and Wang, 2006).

Ecological migration seeks to achieve three objectives: environmental conservation, poverty alleviation, and amelioration of people's wellbeing. It was projected that by 2050, some 10 million people in China would have been resettled, mostly in western mountain regions (Tan et al., 2013). Studies reveal that people's lives have improved after relocation as they have better access to housing, schools, health-care facilities, transportation networks, and market services (Gruschke, 2008). Nevertheless, numerous challenges remain unsolved (West, 2009; Fan et al., 2015). In some cases, relocated people slipped back into poverty and lost their cultural identity; also, traditional customs were seen disrupted, and social networks were disarticulated (Foggin, 2008).

#### 3.2.2. Preventive resettlement of population at high risk for natural hazards

To reduce disaster risks, China has formulated laws, regulations, and policies concerning disaster prevention and management. As a part of a comprehensive risk reduction strategy, preventive resettlement of populations in high-risk areas is deemed an effective and efficient measure that reduces the number of people exposed to hazards, particularly in mountainous environments where the population is sparsely distributed and civil engineering works seem ineffective and costly (Correa, 2011). The document “Regulations on Prevention of Geological Disasters” promulgated by the State Council in 2003 requires that the governments at the county level or above ensure people's life and property at locales prone to geological disasters, either through civil engineering works or preventive relocation. In 2011, the State Council issued the “Decisions on Strengthening Prevention and Mitigation of Geological Disasters”. The directive urged local governments to enhance prevention and mitigation measures through incorporating with other rural development initiatives (e.g., projects relating to poverty alleviation, ecological resettlement, new countryside construction, small-town building, and land renovation) in managing funds and planning, and strengthening efforts to move people away from high-risk areas.

According to “The Thirteenth Five-year Plan for Prevention and Mitigation of Geological Disasters” issued by the central government in 2016, relocation of around 1.4 million people was planned. Notably, an ambitious plan proposed by Shaanxi provincial government calls for about 600,000 rural households comprising 2.9 million people residing in hazard-prone mountain areas of southern Shaanxi to be relocated over the 2011–2020 period. Numerous studies have shown that people relocated under this plan have become less vulnerable to poverty with their livelihood substantially improved (Guo and Kapucu 2018; Yang et al., 2020). However, evidence also shows that some resettled people's livelihoods are more vulnerable than before resettlement, despite reduced exposure to natural hazards. As no farmland has been allocated at the resettlement sites, people may face the risk of impoverishment after relocation although the population is relatively small (Chen et al., 2020).

#### 3.2.3. Relocation of impoverished people from harsh environments

Migration contributes to poverty reduction (Ellis, 2003). In the early 1980s, programs for poverty alleviation were implemented in poverty-stricken regions. As an expedient way to achieve poverty fighting targets, population resettlement was trial led and implemented. The earliest government-sponsored population relocation for alleviating poverty took place in northwestern parts of Gansu province in the 1970s when the Yellow River Diversion Irrigation Project was carried out (Yanget al., 2020). About 1,000 people in Huining county were relocated from its southern poverty-stricken mountain areas to the northern irrigated region from 1973 to 1980 (PRULU, 1983). In 1983, large-scale resettlement programs for poverty alleviation were initiated in northwestern China (mainly in the Liupan

Mountain areas in central Gansu province and the southern Ningxia Hui Autonomous Region). Over 463,000 people were resettled in Gansu by 1999, and 358,000 people had moved in Ningxia by 2001 (Huang, 2004).

Relocation programs were also carried out in poverty-stricken mountain areas in southwestern provinces, particularly in some reservoir areas, including the Three Gorges Project areas, the peripheral mountains of the Sichuan Basin, the Karst areas of Guangxi province, the Yunnan-Guizhou Plateau, and the Tibet Autonomous Region. In total, over 2.56 million people had been resettled through anti-poverty programs by 2000 (Huang, 2004). Official statistics show that 3.9 million people in poverty were relocated from 2011 to 2015. Moreover, 9.8 million people were planned to be resettled for poverty alleviation in 2016–2020, mainly in western China (Rogers et al., 2019).

All mountain areas involving resettlement programs for poverty alleviation share some commonalities: poor accessibility, scarcity of arable land, lack of drinking water, and exposure to natural hazards. For example, Xuri and Xiba, two villages in Zuogong county (*mdzos-gang*) in Tibet, situated at an elevation of 3000m above the sea, had 800 villagers and only 40 ha of arable land. Over 100 villagers had no access to arable land, and 20% of the overall villagers faced food insecurity for three months per annum (Chen, 2004). There would be no hope for people to shake off poverty if not resettled.

#### 4. Conclusions and policy implications

Rural vulnerability is a place-based and multi-dimensional concept. It tends to be more complicated for rural communities in western mountain regions, which are featured by geological instability, environmental fragility, susceptibility to natural hazards, degradation of ecosystem services, and remoteness, marginality, and chronic poverty. With the opening up and reform policy implemented in China since late 1978, rural communities in mountainous areas have undergone drastic social and demographic changes. Apart from policy and related development factors, climate change has a considerable impact on mountain environments and ecosystems, rendering people and communities more vulnerable to natural hazards.

Driven by external socioeconomic forces and affected by the rural vulnerability of mountain areas, rural population migrated out of mountain villages to seek jobs in cities and coastal regions. Many families settled in towns, river valleys, or lowland plains where they have more opportunities and better means of coping with risks and challenges. To eradicate poverty and reverse the degradation of ecologically fragile environments, large-scale ecological resettlement of populations was planned and carried in mountainous regions. Preventive relocation of people in hazard-prone areas has also been carried out in some western provinces. Overall, rural vulnerability has substantially reduced in mountainous areas in various ways, through a myriad of approaches, including spontaneous migration and government-supported resettlement schemes.

However, due to out-migration and the resultant depopulation, the development of traditional villages appear stagnant as old houses become dilapidated, and farmland is abandoned. While some central towns remain dynamic and sprawling along main roads due to an increasing number of rural people purchasing houses and doing businesses, existing infrastructure and social services are overburdened. Addressing these challenges requires overall plans to be in place for rural development (e.g., land-use and integrated rural and urban development plans), keeping abreast of the demographic changes and socioeconomic developments. To curb housing sprawls in rural towns, relevant laws and regulations relating to rural development should be strictly enforced. Public funds for town and countryside development need to be allocated and transferred to communities, providing all people equal access to public and social services (particularly in education, healthcare, and age-pension).

While the exodus of rural populations may be an inevitable trend, vulnerable groups (the aged, disabled, and young children) will stay in mountain villages. Due to their vulnerability and the various risks they face, these groups need exceptional support and assistance. Policy design should consider increasing investment in mountainous regions, building more childcare centers and boarding schools for children left behind, and providing sufficient services and aids for older people (particularly villagers living alone) and other disadvantaged groups.

As mountain areas are home to a catalog of cultural and biological diversities, the promotion of public consultation and participation in the conservation of cultural heritage and management of natural resources and ecosystems is needed. This is particularly the case for ethnic minority groups who enjoy a wealth of indigenous knowledge and experience. Any resettlement programs in such areas should be assessed and evaluated thoroughly. The assessments must evaluate a program's consequences, including the impact on the future sustainability of people's livelihoods in both areas of origin and destination.

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#### References

- Adger W. N., 2006. Vulnerability. *Glob. Environ. Chang.* 16, 268–281.
- Adler, C, Huggel, C, Orlove, B, Nolin, A., 2019. Climate change in the mountain cryosphere: impacts and responses. *Reg. Environ. Chan.*, 19(5), 1225–1228.
- Aleksandrova M., Lamers J.P.A., Martius C., Tischbein B., 2014. Rural vulnerability to environmental change in the irrigated lowlands of Central Asia and options for policy-makers: a review. *Environ.Sci. Policy.* 41, 77–88.
- Alwang J., Siegel P.B., Jorgensen S.L., 2001. Vulnerability: a view from different disciplines. World Bank, Social Protection Discussion Paper Series. No 23304.
- Birkmann J., 2006. Measuring vulnerability to promote disaster-resilient societies: conceptual frameworks and definitions. In Birkmann, J. (Ed.) *Measuring vulnerability to natural hazards: Towards disaster resilient societies.* United Nations University Press, Tokyo.
- Brodnig G., Prasad V., 2010. A view from the top: Vulnerability in mountain systems, Social Development Notes, World Bank, No. 128.
- Chen G., 2004. China Mountain Development Report 2003. Commercial Press, Beijing. In Chinese.
- Chen G., Fang Y., Gao Y., 2010. China Mountain Development Report: New Trends and New Exploration of Mountain Development in China. Commercial Press, Beijing. In Chinese.
- Chen Y., He L., Zhang D., 2021. Consequences of post-disaster policies and relocation approaches: two communities from rural China. *Disaster Prevention and Management.* 30(3), 240–353.
- Chen Y., Tan X., Mao C., 2013. Mountain hazards, risk management, disaster-preventive and poverty-alleviating resettlement. *Journal of Catastrophology.* 28(2), 136–142. In Chinese.
- Correa E., (Ed.), 2011. Preventive Resettlement of Populations at Risk of Disaster: Experiences from Latin America. The World Bank, Washington, D.C.
- Cutter S.L., 1996. Vulnerability to environmental hazards. *Prog. Hum. Geogr.*, 20(4), 529–539.
- Cutter, S.L, Boruff, B.J., Shirley, W.L., 2003. Social vulnerability to environmental hazards. *Soc. Sci. Q.* 84(2), 242–261.
- Deng W., Nan X., Shi Z., Zhang J., Liu B., 2018. Territorial and spatial characteristics and regional development of mountain regions in China. *Chin. J. Nat.* 40(1), 17–24. In Chinese.
- Dickinson D., Webber M., 2007. Environmental resettlement and development on the Steppes of Inner Mongolia, PRC. *J Dev. Stud.* 43(3), 537–561.
- Du Y., Park A., Wang S., 2005. Migration and rural poverty in China. *J. Comp. Econ.* 33, 688–709.
- Eakin H., Luers A.L., 2006. Assessing the vulnerability of social-environmental systems. *Annu. Rev. Environ. Resour.* 31, 365–394.
- Ellis F., 2003. A livelihoods approach to migration and poverty reduction. Department for International Development (DFID), London. <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.553.5678&rep=rep1&type=pdf>.
- Fan M., Li Y., Li W., 2015. Solving one problem by creating a bigger one: The consequences of ecological resettlement for grassland restoration and poverty alleviation

- in Northwestern China. *Land Use Policy*, 42, 124–130.
- Foggin J.M., 2008. Depopulating the Tibetan grassland: National policies and perspectives for the future of Tibetan herders in Qinghai Province, China. *Mt. Res. Dev.* 28 (1): 26–31.
- Gentle P., Maraseni T.N., 2012. Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environ.Sci. Policy*, 21, 24–34.
- Gruschke A., 2008. Nomads without pastures? Globalization, regionalization, and livelihood security of nomads and former nomads in northern Khams. *J. Int. Assoc. Tibet. Stud.* 4, 1 – 40. <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.732.3233&rep=rep1&type=pdf>.
- Guo X., Kapucu N., 2018. Examining the impacts of disaster resettlement from a livelihood perspective: a case study of Qinling Mountains, China. *Disasters*. 42(2), 251–274.
- Halvorson S.J., Hamilton J.P., 2007. Vulnerability and the erosion of seismic culture in mountainous Central Asia. *Geography Faculty Publications*, 3. [https://scholarworks.umt.edu/geography\\_pubs/3](https://scholarworks.umt.edu/geography_pubs/3).
- Hewitt K., 1984. Ecotonal settlement and natural hazards in mountain regions: the case of earthquake risks. *Mt. Res. Dev.* 4(1), 31–37.
- Hewitt K., 1992. Mountain hazards. *GeoJournal*. 27(1), 47–60.
- Hilhorst D., Bankoff G., 2004. Introduction: mapping vulnerability. In: Bankoff, G., Frerks, G., Hiljorst, D., eds., *Mapping Vulnerability: Disasters, Development and People*. Earthscan from Routledge, London/New York, pp. 1–9.
- Huang C., 2004. Voluntary Migration for Poverty Alleviation in Rural China: Theories and Practice. Financial and Economic Press, Beijing, China. In Chinese.
- Huddleston B., Ataman E., d'Ostiani L.F., 2003. Towards a GIS-based analysis of mountain environments and population. Working Paper No 10, Environment and Natural Resources, Food and Agriculture Organization of the United Nations, Rome, 2. <http://www.fao.org/3/y4558e/y4558e.pdf>.
- Ingtu T., 2017. High mountain communities and climate change: adaptation, traditional ecological knowledge, and institutions. *Clim. Change*. 145, 41–55.
- Jansky L, Ives J D, Furuyashiki K, Watanabe T. 2002. Global mountain research for sustainable development. *Global Environ. Chang.* 12, 231–239.
- Kang W., Shao J., Guo Y., 2016. Spatial-temporal distribution and influence factors of population migration in a typical mountainous area, Chongqing. *Tropical Geography*. 36(1), 132–141. In Chinese.
- Leichenko R.M., O'Brien K.L., 2002. The dynamics of rural vulnerability to global change: The case of southern Africa. *Mitig. Adapt. Strategy. Glob. Chang.*, 7, 1–18.
- Liu H., Wuzjati Y., 2013. A new strategy on poverty alleviation in western China. *China Population. Chinese J Popul. Resour. Environ.* 23(10), 52–58. In Chinese.
- Liu, J, Xing C., 2016. Migrate for education: an unintended effect of school district combination in rural China. *ChinaEcon.Rev.* 40, 192–206.
- McDowell G., Ford J.D., Lehner B., Berrang-Ford L., Sherpa A., 2013. Climate-related hydrological change and human vulnerability in remote mountain regions: a case study from Khumbu, Nepal. *Reg. Environ. Change*. 13, 299–310.
- Orlove B., 2009. Glacier retreat: Reviewing the limits of human adaptation to climate change. *Environ. Sci. Policy Sustain. Dev.* 51(3), 22–34.
- Palomo I., 2017. Climate change impacts on ecosystem services in high mountain areas: a literature review. *Mt. Res. Devel.* 37(2), 179–187.
- Pan Z., Wang G., 2018. Rural labor transfer and rural household income in China: a comparison between mountainous and non-mountainous areas. *Popul. Res.* 42(1), 44–59.
- PRULU (Population Research Unit of Lanzhou University), 1983. A preliminary study on population and economic development in Huining County. *N W. Popul.* (4), 1–11. In Chinese.
- Qin H., 2010. Rural-to-urban labor migration, household livelihoods, and the rural environment in Chongqing Municipality, southwest China. *Hum. Ecol. Interdiscip. J* 38, 675–690.
- Renaud F., Jansky L., 2008. Growing risk and vulnerability—The mountain challenge. *Mt. Res. Dev.* 28(2), 166–167.
- Rogers S., Li J., Lo K., Guo H., Li C., 2019. China's rapidly evolving practice of poverty resettlement: Moving millions to eliminate poverty. *Dev. Policy Rev.* 38, 541–554.
- Rogers S., Wang M., 2006. Environmental resettlement and social dis/re-articulation in Inner Mongolia, China. *Popul. Environ.*, 28, 41–68.
- Saldana-Zorrilla S.O., 2008. Stakeholders' views in reducing rural vulnerability to natural disasters in southern Mexico: Hazard exposure and coping and adaptive capacity. *Global Environ. Chang.* 18,538–597.
- Shi P., Li W., 1999. Rehabilitation of degraded mountain ecosystems in southwestern China: an integrated approach. *Ambio*, 28(5), 390–397.
- Tan Y., Zuo A., Hugo G., 2013. Environment-related resettlement in China: A case study of the Ganzi Tibetan Autonomous Prefecture in Sichuan Province. *AsianPac. J* 22 (1), 77–107.
- Turner B.L., Kasperson R.E., Matson P.A., McCarthy J.J., Corell R.W., Christensen L., 2003. A framework for vulnerability analysis in sustainability science. *Proc. Natl. Acad. Sci. The USA*. 100 (14), 8074–8079.
- UNDRR, 2017. Terminology in Disaster Risk Reductio. UNDRR, Geneva. <https://www.preventionweb.net/go/477>.
- Villagran de Léon J.C., 2006. Vulnerability: a conceptual and methodological review. UNU-EHS. SOURCE, Bonn. No 4.
- Wang S., Cao W., 2015. Climate change perspectives in an Alpine area, southwest China: a case analysis of residents' views. *Ecol.Indic.* 53, 211–219.
- Wang Y., 2012. Rural Vulnerability to Earthquake Disasters in China. Science Press, Beijing. In Chinese.
- Watson R.T., Haerberli W., 2004. Environmental threats, mitigation strategies and high-mountain areas. *Ambio, Special Report*. 13, 2–10.
- Weichselgartner J., 2001. Disaster mitigation: the concept of vulnerability revisited. *Disaster Prevention and Management*. 10(2), 85–94.
- West J.J., 2009. Perceptions of ecological migration in Inner Mongolia, China: summary of fieldwork and relevance for climate adaptation. CICERO, Oslo. Report 05.
- Wisner B., Blaikie P., Cannon T., Davis I., 2004. *At Risk: Natural Hazards, People's Vulnerability and Disasters* (Second Edition). Routledge, London
- Xu, J., Grumbine, R.E, Shrestha, A., Eriksson, M., Yang, X., Wang, Y., 2009. The melting Himalayas: cascading effects of climate change on water, biodiversity, and livelihoods. *Conserv.Biol.* 23(3), 520–530.
- Yang Y., de Sherbinin A., Liu Y., 2020. China's poverty alleviation resettlement: Progress, problems and solutions. *Habitat Int.* 98.
- Zhao Y., 1999. *Pattern Distribution of Ecologically Fragile Environment and Comprehensive Restoration in China*. China Environmental Science Press, Beijing. In Chinese.
- Zheng Y., Byg A., 2014. Coping with climate change: households' response strategies to drought and hailstorm in Lijiang, China. *Environ. Hazards*. 13(3), 211–228.
- Zhou L., Xiong L.Y., 2018. Natural topographic controls on the spatial distribution of poverty-stricken counties in China. *Applied Geography*. 90, 282–292
- Zhu N., Luo X., 2010. The impact of migration on rural poverty and inequality: a case study in China. *Agricultural Economics*. 41, 191–204.