

## Addressing Drought Prevention and Mitigation in Mountain Agricultural Development in Southwest China

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**Abstract.** Drought is a slow-onset, creeping natural hazard that is a normal part of climate for Southwest China. The impacts of drought are largely nonstructural and spread over a larger geographical area than are damages from other natural hazards. Mountain agriculture of Southwest China with its fragile ecosystems is particularly vulnerable to droughts. Sustainable mountain agricultural development provides essential ecosystem services and are main food sources for people living in downstream slopes, valleys, and plains. The paper elaborates the specific vulnerability contexts and situation of mountain agricultural systems, highlights the importance of mountain agriculture development for mountain people as well as downstream communities, and also explores the opportunities that are created by climate change.

**Keywords:** drought; prevention and mitigation; mountain agricultural development; Southwest China

### 1. Introduction

Mountain areas cover more than 90% of Southwest China's land surface (see TABLE I) and are repositories of biological and cultural diversity and provide vital services with a tangible economic value – such as food, water, power, tourism, minerals, medicinal plants, and fibers – to mountain communities and, even more important, to often heavily populated downstream areas. Mountain areas of Southwest China are ethno-culturally very diverse (see TABLE II), with a high diversity of agricultural development. These people often guard a vast body of traditional ecological knowledge on how to sustainably manage the agricultural land in a challenging mountain environment. Their traditional land management practices (e.g., trenching, terracing, and irrigation systems) are still crucial today for low-intensity production systems at high altitudes.

TABLE I. THE PROPORTION OF MOUNTAIN AREAS IN SOUTHWEST CHINA

Province	Area (10 <sup>4</sup> km <sup>2</sup> )	Proportion of mountain areas (%)
Guizhou	17.60	95.1
Yunnan	39.40	95.0
Sichuan	48.50	94.7
Chongqing	8.24	86.9
Xizang	122.84	76.5

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TABLE II. THE DISTRIBUTION OF ETHNIC MINORITIES IN MOUNTAIN AREAS OF SOUTHWEST CHINA

Mountains	Ethnic minorities
Hengduan Mountains	Tibetan, Yi, Miao, Hui, Mongolian, Qiang, Bai, Nahsi, Nu, Wa, Lisu, Tulung, Pumi, Dai, Chingpo, Hani, Jinuo, Lahu, Pulang, Achang, Penglung.
Himalaya Mountains	Tibetan, Manba, Lopa
Min Mountains	Tibetan, Qiang, Hui.
Wumeng Mountains	Yi, Miao, Puyi.
Dalou Mountains	Tujia, Miao, Yi, Gelao.
Miaoling Mountains	Miao, Dong, Puyi, Shui, Gelao.

Mountain environments of Southwest China are highly fragile and agricultural development in mountain areas are exposed to a system of environmental and non-environmental stressors which are interlinked and have serious repercussions on mountain people's livelihoods. These stressors include growing populations, which linked to increasing demand and globalization increase the pressure on water, land, and other natural resources and services. In this context, drought acts as an additional stressor which can multiply existing development deficits and reverse progress in mountain areas [1] and may limit mountain people's inherent capacity to cope and adapt. Drought is a slow-onset, creeping natural hazard that is a normal part of climate for Southwest China. The impacts of drought are largely nonstructural and spread over a larger geographical area than are damages from other natural hazards. Extreme drought events can affect agriculture, industry, municipalities, tourism, recreation and environmental protection. Among the various water uses, the most vulnerable ones during drought are those related to environmental protection and agriculture. Agricultural production is affected by drought, because it is directly dependent on water availability, which is limited under drought. However, the impacts of drought, like those of other hazards, can be reduced through prevention and mitigation. The significance of the impacts of drought on the agricultural sector should be assessed taking into account the severity of the drought (magnitude and duration of the drought episode) and the vulnerability of the agricultural system [2]. Fragility and vulnerability to climate and other drivers of change, along with growing scarcity of fresh water and energy as a basis for economic growth, have created not only new challenges but also new opportunities and possibilities for mountain agricultural development of Southwest China. Examples for emerging opportunities include a growing demand for high-value mountain niche products, payments for ecosystem services, and potential for carbon sequestration to name just a few.

## 2. Increasing Vulnerabilities to drought in Mountain agriculture of Southwest China

### 2.1 Global climate change exacerbates the impacts of drought

It is widely recognized that mountain regions of Southwest China are particularly vulnerable as a result of their high relief, steep slopes, shallow soils, adverse climatic conditions, and geological variability [3]. Mountain agriculture is subject to a variety of drivers of change including globalization; economic policies; and increasing pressure on land and mountain resources due to economic growth and changes in population and lifestyle. Global climate change acts as an additional stressor which is expected to exacerbate the impacts of other drivers of change. Regardless of the high degree of uncertainty, it is clear that the biophysical fragility of mountain ecosystems has direct consequences for the socioeconomic vulnerability of mountain people [4]. Vulnerability to drought is increasing in mountain agricultural development of Southwest China. Mountain regions have experienced above-average warming in the 20th Century [5], which has significant implications

for mountain environments and environmental processes. In the Predictions for the 21st Century indicate that temperatures will continue to increase disproportionately in mountain areas. The greatest temperature rise under the four IPCC Special Reports on Emissions Scenarios is expected in high- and medium-latitude mountains, including the high-latitude mountains of Asia are expected to experience the greatest changes in temperature [6]. The most noticeable impact of climate change in mountains is the recession of glaciers. These alterations in the cryosphere are already leading to changes in land surface characteristics and drainage systems and are very likely to have significant repercussions on water availability for mountain agricultural development and downstream communities [7]. With global warming, it is likely that the hydrological cycle in mountain areas will intensify, changing the frequency and intensity of floods and droughts [8].

With climate change, it has been predicted that the frequency and magnitude of extreme events, including droughts, will increase [9]. This is expected to have significant implications for fragile mountain ecosystems as well as for mountain livelihoods and infrastructure. Mountains, in general, are considered highly vulnerable, and knowledge about the impacts of drought on agricultural development is lacking. However, to sustain and enable current economic development in the mountains, it will be crucial to address the issue of drought and its relationship with agricultural development through adaptation measures. Drought is threatening sustainable development, especially poverty alleviation, in the mountains since a single extreme event such as a drought can destroy major livelihood resources such as standing crops and rangeland. The mountain poor will face more serious impacts in future due to the likelihood of more and more frequent occurrences of extreme events, and their economic development prospects are increasingly facing risks. The underlying causes of vulnerability include disproportionate poverty rates, high prevalence of slope cultivated land (see TABLE III ), high dependency on natural resources, marginalization, and limited livelihood diversity. These factors, are the driving forces of mountain people's vulnerability, and are expected to be further aggravated by droughts.

TABLE III. SLOPE CULTIVATED AREAS IN SOUTHWEST CHINA

Region	Cultivated area( $10^4\text{hm}^2$ )	The proportion of $15^\circ \sim 25^\circ$ slope cultivated land	The proportion of no less than $25^\circ$ slope cultivated land
China	13488	9.6	4.5
Chongqing	258	31.4	16.1
Sichuan	679	24.2	9.7
Guizhou	506	30.4	19.5
Yunnan	657	33.7	13.0
Xizang	35	11.2	3.6

## 2.2 Poverty, marginalization and drought

Mountain poverty has to be understood in the light of several mountain-specific constraints which intensify the prevalence of poverty. These include fragility of ecosystems; remoteness; poor accessibility and marginalization of mountain communities from the mainstream; lack of equity in terms of access to basic agricultural facilities such as irrigation systems, as well as to markets, political power, and representation; lack of employment opportunities; and proneness to natural disasters [10]. The vast majority of rural mountain people engages in some form of agricultural activity and is thus highly dependent on natural resources. Intensive mixed farming systems are the most common form of agriculture at lower altitudes in the highlands. However, due to environmental constraints such as unfavorable climatic conditions, poor-quality or shallow soils, and sloping terrain, productivity is generally low and harvest output is not competitive in the global market. At higher altitudes, where mountain environments are harsh and suitability for agriculture is restricted, pastoralism is the most common livelihood strategy. Pastoral systems, however, are becoming increasingly vulnerable due to population growth and the resulting increasing pressures on the land, the impacts of more frequent and severe droughts, and the breakdown of traditional trade routes and patterns of exchange [11].

Droughts may further reduce the competitiveness of agriculture-based mountain livelihood systems; it may result in increased pressure on already stressed fragile landscapes (see Fig.1).

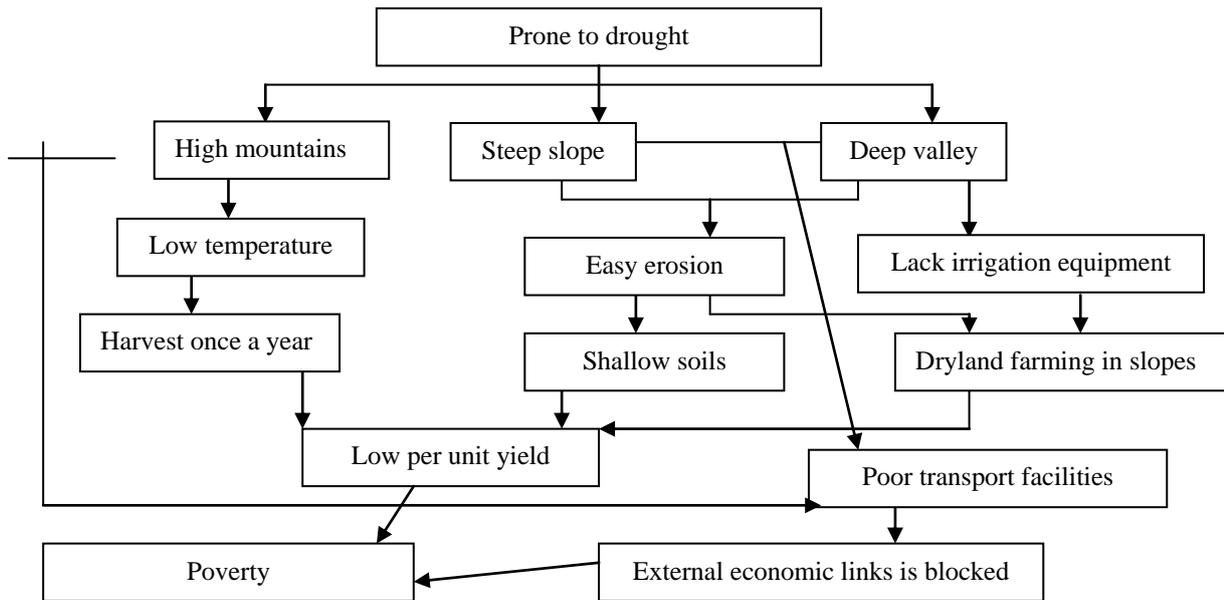


Fig. 1: Unfavorable agricultural development status in mountain areas of Southwest China

### 2.3 Livelihood options besides agriculture depend on sustainable mountain agricultural development

The livelihood options of mountain communities besides agriculture are often restricted, mainly due to the poor accessibility of the areas in which they live. However, there are new opportunities emerging which may gain in importance as alternative livelihood strategies in the future. Tourism is a major livelihood strategy in mountain areas of Southwest China and is a major source of foreign exchange and is one of the few factors that stabilizes mountain populations and deters people from migrating. Like agriculture, the tourism industry is highly sensitive to changes in environmental conditions. It depends on pristine landscapes, high biological diversity, and well-managed protected areas, which serve as important tourist destinations, and, in the case of eco-tourism, on reliable sustainable agricultural development. On the other hand, with rising temperatures, cool mountain resorts in Southwest China may increase in popularity and provide important new livelihood options as summer destinations for people who wish to escape the heat in the lowlands.

## 3. Drought Prevention and Mitigation Measures

### 3.1 Emphasis on risk management

Drought risk is a product of a region's exposure to the natural hazard and its vulnerability to extended periods of water shortage [12]. If Southwest China governments are to make progress in reducing the serious consequences of drought, they must improve their understanding of the hazard and the factors that influence vulnerability. It is critical for drought-prone mountain regions to better understand their drought climatology (i.e., the probability of drought at different levels of intensity and duration) and establish comprehensive and integrated drought management that incorporate climate, soil, and water supply factors such as precipitation, temperature, soil moisture, reservoir and lake levels, ground water levels, and stream flow. Southwest China governments should develop regional drought policies and prevention measures that place emphasis on risk management rather than following the traditional approach of crisis management, which decreases self-reliance and increases dependence on government and donors. The drought policy should be an emphasis on risk management through the application of prevention and mitigation measures. Prevention refers to pre-disaster activities designed to increase the level of readiness or improve operational and institutional capabilities for responding to a drought episode. Mitigation is short- and long-term actions, programs, or policies implemented during and in advance of drought that reduce the degree of risk to human life, property,

and productive capacity. These actions are most effective if done before the event. Emergency response will always be a part of drought management because it is unlikely that government and others can anticipate, avoid, or reduce all potential impacts through mitigation programs.

### **3.2 Monitoring and Early Warning Systems**

Monitoring drought presents some unique challenges because agricultural drought is best characterized by deficiencies in soil moisture. This parameter is a critical factor in defining crop production potential. The shortcomings of current drought management were noted in the following areas [13]: Data networks: inadequate density and data quality of meteorological and hydrological networks and the lack of data networks on all major drought and water supply parameters; Data sharing: inadequate data sharing between government agencies and the high cost of data limits the application of data in drought prevention, mitigation, and response; Early warning system products: data and information products are often not user friendly and users are often not trained in the application of this information to decision making; Drought forecasts: unreliable seasonal forecasts and the lack of specificity of information provided by forecasts limit the use of this information by farmers and others; Drought monitoring tools: inadequate indices for detecting the early onset and end of drought, although the Standardized Precipitation Index was cited as an important new monitoring tool; Integrated drought monitoring: drought monitoring systems should be integrated and based on multiple indicators to fully understand drought magnitude, spatial extent, and impacts; Impact assessment methodology: lack of impact assessment methodology hinders impact estimates and the activation of mitigation and response programs; Delivery systems: data and information on emerging drought conditions, seasonal forecasts, and other products are often not delivered to users in a timely manner.

### **3.3 Drought prevention and mitigation Plans**

Drought prevention plans provide the framework for improved coordination within and between levels of government. Early warning and monitoring systems are more comprehensive and integrated and the delivery of this information to decision makers at all levels is enhanced. Through drought plans, the risks associated with drought can be better defined and addressed with proactive mitigation and response programs. The drought prevention planning process also provides the opportunity to involve numerous stakeholders early and often in plan development, thus increasing the probability that conflicts between water users will be reduced during times of shortage. Drought mitigation plans have three essential components. First, a comprehensive early warning system provides the basis for many of the decisions that must be made by a wide range of decision makers as drought conditions evolve and become more severe. Equally important, early warning systems must be coupled to an effective delivery system that disseminates timely and reliable information. Second, a critical step in the development of a mitigation plan is conduct of a risk assessment [14] to determine who and what is at risk and why. Third, after impacts have been identified and prioritized, the next step is to identify appropriate mitigation actions that can help to reduce the risk of each impact for future drought events.

### **3.4 Agricultural extension programs**

Agricultural extension programs represent a proactive approach to drought management which included a wide range of measures such as lowering of well intakes on reservoirs for rural water supplies, establishing water hauling programs for livestock, and creating a tuition assistance program to enable farmers to participate in farm management classes.

#### *1) Farmer Irrigation Education*

Recommend that farmers attend classes in best management practices and conservation irrigation, prior to ( i )receiving a permit, ( ii )using a new irrigation system, or (iii)irrigating for a coming announced drought season; Provide continuing education opportunities for farmers; Encourage conservation irrigation, efficient use of irrigation systems, and the Cooperative Extension Service's water conservation guidelines; Encourage development and distribution of information on water efficient irrigation techniques.

#### *2) Field or Crop Type Management*

Encourage the use of more drought resistant crops; encourage the use of innovative cultivation techniques to reduce crop water use; Conduct crop irrigation efficiency studies; provide farmers with normal year, real

time irrigation, irrigation scheduling, and crop evaporation/transpiration information; Monitor soil moisture and provide real time data to farmers.

### *3) Irrigation Equipment Management*

Encourage the installation of water efficient irrigation technology; Retrofit older irrigation systems with newer and better irrigation technology. Update any system over ten years old; Encourage farmers to take advantage of available financial incentives for retrofitting and updating older or less efficient systems; Recommend irrigation system efficiency audits every 5 years. Improve irrigation permit data to create a high degree of confidence in the information on ownership, location, system type, water source, pump capacity, and acres irrigated for all irrigation systems to determine which watersheds and aquifers will be strongly affected by agricultural water use, especially in droughts; Improve on the agriculture irrigation water measurement and accounting statewide; Improve communications and cooperation among farmers and relevant state and Federal agencies regarding available assistance during drought conditions; Support legislation and efforts to enhance the ability of farmers to secure adequate water supplies during drought conditions.

## **3.5 Rewards for Mountain Ecosystem Services**

Upstream-downstream linkages: Mountain areas are vital providers of resources and services. Mountain areas support many different ecosystems and provide key resources and services for human activities well beyond their natural boundaries. Whereas most of the goods and services provided by mountain areas of Southwest China, the consumers of these goods and services are mostly in the lowlands. Highland and lowland systems are thus highly interdependent in terms of ecology and sustainable agricultural development as well as in social and political terms. Mountain communities with their traditional ecological knowledge contribute significantly to the quality and the sustainable management of these goods and services. However, they are rarely compensated fairly for the services they provide to downstream communities. The goods and services provided by mountain ecosystems and sustainable agricultural development can be divided into three major groups: provisioning services; regulating and supporting services; and cultural services. Mountain people, through their still predominantly sustainable land management practices, provide a number of positive externalities (non-market side effects of an sustainable agricultural development) including (agro-) biodiversity conservation; carbon sequestration and climate mitigation; soil protection and preservation; water or watershed management; protection from and prevention of natural hazards (e.g., droughts); and preservation of cultural and natural landscapes for recreation [15]. So far, there are only a few examples of mountain people being rewarded for such services, in part because there is a lack of public awareness and a lack of valuation of the importance of mountain ecosystem services and of the people serving as stewards for these services.

## **3.6 Sharing of Good Practices and Capacity Building**

With regard to adaptation to and mitigation of droughts, while funds to implement interventions are necessary, knowledge about successful mechanisms and up-to-date technology may be even more relevant. In this context, greater financial means to test and implement sustainable mountain agricultural development could play crucial roles in providing knowledge and expertise to, and building the capacities of, Southwest China. Furthermore, traditional knowledge on coping and adaptive mechanisms to droughts needs to be better understood. Overall, good practices of climate change adaptation and mitigation – both modern and traditional – need to be documented and disseminated through training and education initiatives that are tailored to the needs of mountain environments and people.

## **4. Conclusions**

Because of its slow-onset characteristics and lack of structural impacts, drought is often disregarded. It is often considered to be a departure from normal climate; thus the lack of emphasis on prevention and mitigation. Improved understanding of the different types of drought and the need for multiple definitions and water supply indicators that are appropriate to mountain agricultural development is a critical part of this awareness-building process. Evidence illustrates that there is an escalating trend of agricultural losses

associated with drought in mountain areas of Southwest China. It is important to understand the factors behind our vulnerabilities and take proper steps to reduce those vulnerabilities. Reducing drought risk is largely about changing behaviors, thus social scientists must play a key role in the drought planning process. A challenge is to convince policy and other decision makers that investments in mitigation are more cost effective than post-impact assistance or relief programs.

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