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Author: Irasema Alcántara-Ayala
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Irasema Alcántara-Ayala

Flowing Mountains in Mexico

Incorporating Local Knowledge and Initiatives to Confront Disaster and Promote Prevention

Disasters associated with mountain hazards have had considerable impact throughout the world, especially in least favored regions such as Asia and Latin America—as illustrated by the case of Puebla Province in the Sierra Norte, Mexico, devastated by an extreme precipitation event in October 1999. The effect of disasters on mountain areas depends on the spatial and temporal distribution of hazards, as well as the degree of vulnerability faced by the population. Given the nature of the planet, it is rather difficult to control hazards in terms of actual processes. The key to reducing disasters and their impacts is thus to focus on decreasing vulnerability and promoting prevention. The latter can be achieved to some extent by incorporating local knowledge and initiatives into the framework of public policy and decision-making.

Flowing mountains: the case of the Sierra Norte, Puebla

Of the different hazards that occur in mountains, landslides are of major significance in areas with isolated communities. In the particular case of Mexico, the recent effects of mass failure (Figure 1) have demonstrated the importance of developing adequate strategies, not only to confront disasters but also to promote prevention.

FIGURE 1 Hundreds of mass movement processes were triggered by an extreme rainfall event in 1999, causing considerable human and infrastructure losses in the Sierra Norte, Puebla. (Photo by Irasema Alcántara-Ayala)

Extensive damage, calculated at US$ 457.37 million (Table 1), was caused in the provinces of Hidalgo, Veracruz and Puebla by the combination of a tropical depression and a cold front in October 1999. Flooding and landslides took place, producing casualties and destruction. Puebla Province was the most affected area, due to mass movement processes. Rainfall-induced landslides were triggered by cumulative precipitation ranging from 743 to 844 mm in several localities during a 4-day period. This amount of rain is equivalent to about 50% of the mean annual value.

Puebla Province is located in the transition zone between 2 physiographic provinces: the Sierra Madre Oriental, composed of sedimentary rocks covered in some parts by volcanic deposits, and the Trans-Mexican Volcanic Belt, which consists of a series of Late Tertiary and Quaternary strato-volcanoes, cinder cones, calderas, domes and maars, mostly calc-alkaline. The northeastern region of this province is known as Sierra Norte, where hundreds of mass failures took place, producing considerable damage in 81 municipalities and claiming many victims. Official statistics indicated that 263 people lost their lives due to the floods and landslides associated with this event, although the native population believes the number of fatalities was greater. Most of the casualties occurred in Teziutlán, where around 130 people were buried by a single landslide in the Aurora neighborhood. In Zacapoaxtla, landslides also caused 16 casualties and substantial damage to infrastructure.

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TABLE 1 Costs of damage caused by the extreme rainfall event of 1999 in the province of Puebla. (Source: Bitrán and Reyes 2000)

Sectors	Costs in million US$		
	Direct damage	Indirect damage	Total per sector
Social sector	**50.50**	**1.5**	**52.00**
Housing	48.61	0	48.61
Education	1.64	1.5	3.14
Health	0.25	—	0.25
Services and infrastructure	**154.00**	**0.1**	**154.10**
Water	8.46	0.18	8.64
Energy	48.11	—	48.11
Communications and transport	97.43	—	97.43
Productive sector	**19.07**	**3.5**	**22.57**
Agriculture	13.25	3.5	16.7
Livestock production	1.54	—	1.54
Forestry	3.5	—	3.5
Fishing	0.78	—	0.78
Overall total	**447.14**	**10.28**	**457.37**

Bio-physical and human factors

The Sierra Norte consists of several mountain areas, including Zacapoaxtla, Huauchinango, Teziutlán, Tetela de Ocampo, Chignahuapan, and Zacatlán, where altitudes of 4282 m are reached. These areas, as well as diverse communities located at lower altitudes but in inaccessible regions, were considerably damaged by the event of 1999, and even now are exposed to potential landslides (Figure 2).

The likely impact of landslide-associated disasters in this region illustrates the conditions of extreme risk and the great vulnerability faced by mountain communities in all parts of the world. The magnitude of disasters is determined in particular by high levels of marginality, lack of well-established educational schemes, unemployment, poor housing conditions, the scarcity of health services, and scanty infrastructure and communication systems.

From a geomorphic point of view, landslides are determined by the geological setting of the area in terms of lithological units, material properties, and local relief conditions on steep slopes. Shallow landslides were the most widespread type of failure associated with the October precipitation event. They occurred mainly on ignimbrite deposits, or in the contact area between sedimentary and volcanic materials. Ignimbrites easily induced the infiltration and development of a perched water table that caused slope instability, owing to the contrasting levels of permeability of ash-fall deposits, which in some locations are interbedded with paleo-soils. Lithological contacts between sedimentary rocks such as limestones also play an important role in the development of slide surfaces when they are overlaid by ash-fall deposits. In addition, highly weathered limestone is a source of structural weakness, decreasing the strength of the materials involved. It is also worth mentioning that on a regional scale, landscape evolution in mountain areas can be easily related to the interface of transport processes and the development of steep gradients derived from uplift, fluvial undercutting, etc, where landslides play an important role in shaping the Earth's surface. Therefore, landforms associated with the occurrence of ancient mass

FIGURE 2 Several communities are located on slopes where landslides occurred long ago, and the risk of new landslides occurring remains high. (Photo by Irasema Alcántara-Ayala)

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movement processes are particularly widespread in the Sierra Norte, as in other mountain regions. Consequently, reactivation of failures on potentially unstable hillslopes turns out to be a familiar hazard in the area.

Apart from these geomorphic factors, human activities also influence the stability of the natural environment and increase the landslide risk in the Sierra Norte. Based on field observations and analysis of land use change using satellite images, it has been suggested that deforestation has played a significant role in making areas susceptible to failure. During the extreme precipitation event of October 1999, approximately 40% of the total failures occurred in areas with vegetation removal or where land use changes had taken place, showing an elevated incidence of instability. Additionally, in several localities where landslides affected housing, lack of well-established drainage and sewer systems provoked water concentration, infiltration, and development of potential and actual slide surfaces.

Natural hazards, vulnerability, and participatory risk management

Natural hazards can be defined as physical events or phenomena capable of producing damage in a defined space and time, and vulnerability as the propensity of an endangered element to suffer loss or damage depending on its particular social, economic, cultural, and political weaknesses (Alcántara-Ayala 2002). Risks and disasters associated with landslides in mountain areas today are thus the result of the coexistence of an unstable landscape and the vulnerability of communities influenced by local underdevelopment and the intention to make a national transition towards a globalized world.

Vulnerability is determined by environmental, social, economic, cultural and political factors:

- *Environmental factors* are associated with human–nature interactions related to resource use. In the Sierra Norte and other similar contexts, this is represented by the exploitation of forest resources and land use change.
- *Social organization* is a key issue when assessing vulnerability, since organization of institutions at the municipal level requires the participation of communities in accordance with local needs and concerns. Hence social vulnerability is determined to some extent by the ability to organize a community in such a way that fundamental values (eg, collaboration, authenticity and legality) are taken into account by everyone.
- *Economic vulnerability* usually influences the degree of community development, in terms of settlements and lack of rural–urban planning.
- *Cultural factors* that increase vulnerability are generally associated with traditional myths, beliefs and cosmovisions concerning the occurrence of disasters as a result of (a) God's will. Moreover, lack of education regarding physical phenomena or how to develop a culture of prevention, has a direct impact on the consequences of disasters.
- Decision-making is related mainly to *political vulnerability*, where local actors are not always considered in the process, and therefore external interests might interfere in solving local problems related to risk management.

Scenarios associated with the occurrence of disasters are complex systems that need to be assessed from interdisciplinary and transdisciplinary points of view. Such approaches need to address, in a parallel and integrated manner, the interactions between hazards and the types of vulnerability in each threatened community. However, in order to develop adequate strategies of risk management focused on disaster prevention, it is necessary to take into account local actors' opinions, as well as their understanding of vulnerability levels. Thus it is advisable to promote the development of a culture of community participation (Figure 3), and to ensure that the population feels empowered as a significant actor in decision-making processes related to risk management.

Upcoming agendas

In a practical sense, more careful and more efficient assessment of hazard and

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FIGURE 3 Involvement of local actors is a key to development of adequate strategies for disaster prevention. The high level of vulnerability of the local population is also reflected in poor housing conditions. (Photo by Irasema Alcántara-Ayala)

disaster processes in mountain areas in least favored countries is undoubtedly urgent. On the one hand, there is a lack of scientific research regarding instrumentation, monitoring and modeling in these areas, and a need to better understand the processes themselves, including the potential impact of extreme rainfall events and the role deforestation plays in soil hydrology. On the other hand, considerable further attention is needed to assess the vulnerability levels within communities. When conducting vulnerability research, it is crucial to consider factors such as social, economic, political and cultural issues, which ultimately determine the predisposition of the endangered communities to confront disasters.

Confronting disasters and promoting prevention necessarily requires incorporation of local actors into the risk management agenda. Public policies and decision-making must not lie only within the hands of outside authorities and specialists who are not familiar with the cultural and social practices of a community. Therefore it is important to take into account the situation and the peculiarities of each community; encourage feedback between local actors and experts; make sure solutions correspond to actual needs by providing social support for scientific, technical or administrative decisions; and promote local community participation. Finally, the development of risk management systems to promote prevention is urgently required, in order to minimize the consequences associated with disasters of any magnitude. Such systems need to take account of historical processes in the community concerned, in terms of potential hazards and vulnerability, and also encourage organization of local groups that understand the links between human beings and nature.

Prevention therefore depends on increased local, regional and global sustainability, which implies that equilibrium among dynamic natural and human processes must always be sought. It is important to bear in mind that disasters are not always triggered by extraordinary natural events but are the result of a lack of risk management processes, creating conditions that people from isolated communities in mountain areas endure on a daily basis. Ideally, the necessity of confronting mountain disasters should be supplanted by a coherent system promoting prevention.

AUTHOR

Irasema Alcántara-Ayala
Department of Physical Geography, Circuito Exterior, Ciudad Universitaria, Coyoácan 04510, Mexico.
irasema@igiris.igeograf.unam.mx

Irasema Alcántara-Ayala is a geomorphologist working as Associate Professor at the Institute of Geography, National Autonomous University of Mexico (UNAM). Her research focuses on mass movement processes, natural hazards, risks, and prevention of natural disasters.

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