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On the historical account of disastrous landslides in Mexico: the challenge of risk management and disaster prevention

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Abstract. Landslides disasters in Mexico caused more than 3500 deaths between 1935 and 2006. Such disasters have been mainly associated to intense precipitation events derived from hurricanes, tropical storms and their interactions with cold fronts, although earthquake triggered landslides have also occurred to a lesser extent. The impact of landsliding in Mexico is basically determined by the geomorphic features of mountain ranges and dissected plateaus inhabited by vulnerable communities. The present contribution provides a comprehensive temporal assessment of historical landslide disasters in Mexico. Moreover, it aims at exploring the future directions of risk management and disaster prevention, in order to reduce the impact of landslides on populations as a result of climatic change, urban sprawl, land use change and social vulnerability.

1 Introduction

The impact of disasters all over the world has lead to worsening dilemmas for development. Particularly in Mexico, as its nature determines the occurrence of natural hazards (i.e. volcanic eruptions, earthquakes, hurricanes and landslides), social conditions derived from urban growth, high population density, poverty, and inequality, play a significant role in creating vulnerability. Therefore, the risk of disasters is nowadays generally constructed by coupling hazards and vulnerability under the influence of diverse factors such as climatic and land use changes, among others.

Research and resources have been devoted to a great extent to the understanding of various types of natural hazards, however, it isn't until the last few years that landslides have received some attention (Alcántara-Ayala, 2004; Lugo et al., 2005). Consequently, an exhaustive analysis of their spatial and temporal dimension is still under progress. Particularly, Evans and Alcántara-Ayala (2007) have examined the major disasters resulting from landslides, snow avalanches, and geotechnical failures in North America. In a parallel research exercise and as an attempt to assess the incidence of landslides in Mexico through time, a historical account of the most disastrous landslides during the period 1935–2006 has been undertaken. The latter was carried out based on historical archives (newspapers), scientific papers and the "desinventar" disaster database (http://www.desinventar.org/). It is important to stress, nonetheless, that even though the data may possibly involve some variability and uncertainty, primarily in terms of the number of deaths – as can be expected – this effort represents a first step in establishing a landslide impact perspective at national level. Information derived from the three main sources was crossed-checked and database will continue being updated and improved.

In exploring the literature, it is clear that natural hazard assessment has been undertaken successfully at different scales in several regions of the world (Glade et al., 2005; Van Westen et al., 2006). It is however the issue of defining vulnerability and risk, one of the most controversial aspects that remains unclear within the disaster notion framework. The latter results from the variety of existing epistemological orientations and methodological approaches developed by a wide range of disciplines and experts (Barkun, 1974; Maskrey, 1993; Blaikie et al., 1994; Cannon, 1994). Particularly in this paper, natural hazards are understood as all physical phenomena that can negatively affect human-kind in terms of their living standards, structures, or activities, whereas vulnerability is the propensity of an endangered element to suffer different degrees of loss or amount of damage depending on its particular social, economic, cultural, and political weaknesses (Blaikie et al., 1994; Alcántara-Ayala, 2002).

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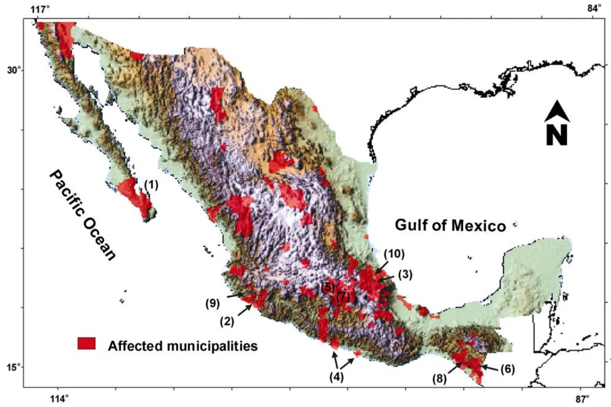

Fig. 1. Municipalities affected by landslide disasters in Mexico, 1935–2006 (Numbers correspond to the top ten disasters reported on Table 1).

2 Landslide databases and inventories

The comprehension of landslide mechanisms and dynamics is frequently based on the analysis of mass-failure occurrence through time (in short and long terms) and space (small, medium and large-scales). Therefore, landslide databases and inventories can be regarded as one of the primary ingredients for such understanding. Both have been primarily developed by using historical archives (Ibsen and Brundsen, 1995; Ibsen et al., 1995; Calcaterra and Parise, 2001; Glade 2001; Glade et al., 2001) and bibliography (Alger, and Brabb, 2001; Keefer, 2002), field observations, mapping (Parise, 2000; Ayenew and Barbieri, 2005), aerial photographs, geographical information systems (Chau et al., 2004), satellite (Nichol and Wong, 2005), radar (Berardino et al., 2003) and LIDAR (Van Den Eeckhaut et al., 2007) imagery.

Databases and inventories are constructed in line with the available human and economic resources, and depending on the pursued goals. As indicated by Malamud et al. (2004) landslide inventories are comprised within two categories: (a) historical inventories: landslide events over time in a specific area; and (b) landslide-event inventories associated to a particular trigger. In addition to those conditions, landslide type, can also be included as a third class. Accordingly, a series of historical landslide inventories have been produced for many regions in the world (Ayenew and Barbieri, 2005; Duman et al., 2005 among others). Common examples of landslide-event inventories include rainfall (Guzzetti et al., 2004) and earthquake (Mahdavifar et al., 2006) triggered landslides, whereas specific types, such as rock falls in Hong Kong (Chau et al., 2003), have also been developed.

Quality, completeness, accuracy and limitations of datasets vary from place to place and according to the reconnaissance techniques (Wills and McCrink, 2002) and ground conditions (Brardinoni et al., 2003). Nonetheless, their value and significance have been clearly expressed by quite a number of research assessments and publications in terms of hazards, erosion rates estimations (Malamud et al., 2004a), along with other domains. What is more, Malamud et al. (2004b), formulated a landslide probability distribution that can be used to calculate landslide-event magnitudes for incomplete inventories.

3 Spatial-temporal distribution of landslide disasters in Mexico

A total death toll of 3514 resulted from the occurrence of forty disastrous landslides and associated geotechnical failures in Mexico during the period 1935–2006 (Fig. 1). Nonetheless, it is relevant to point out that since records concerning the impact of this type of hazard are rather scarce, without a doubt, losses might have been greater. Despite the existing large controversy about defining a disaster, in this case, for practical reasons, only events which involved at least 10 fatalities were considered for the analysis. Particularly, in this section, attention was given to the top ten disasters reported for the specified period (Table 1), which amounted 3153 deaths, in other words, it corresponds to 90% of the total cases that took place during the analyzed time interval.

The worst episode, which involved 1000 casualties, took place in La Paz in September 1976 as a result of a geotechnical failure; flash-floods and mudflows were generated by the collapse of a six-meter dike produced by the intense precipitation of Hurricane Liza. Given the lack of rain gauges, based on indirect measures, Vázquez et al. (1997), estimated a rainfall of 180 mm for 30 September, and a consequent flow rate of 950 m^3/s over a 7.5 h period. The strong current and the large volume of water carried by El Cajoncito stream caused the collapse of the dyke. The resulting 2 m height avalanche washed away the human settlements formed to a major extent by wood and cardboard housing; 10 000–12 000 people were left homeless.

The second largest disaster, also associated to a hurricane, caused 871 human deaths in Minatitlán, Colima in 1959 (Lugo and Flores, personal communication; Davis, 2002). Although establishing the specific number of deaths has caused controversy (Corona-Esquivel et al., 2002), this episode was with no doubt one of the most tragic events associated to landsliding in Mexico. After three days of intense precipitation, due to rainfall triggered landslides a natural dam was formed in the area of the Copales and Juanillos hills. Later on, catastrophic overtopping of the dam caused three mudflows that swept onto the town of Minatitlan (Padilla, 2006).

Most recently, in October 1999, the interaction of a tropical storm and a cold front generated intense rainfall in the region known as Sierra Norte de Puebla; hundreds of landslides took place and 247 people died (Bitrán, 2000). The area is

Table 1. The ten top most disastrous landslides in Mexico (1935–2006).

National Rank	Locality	State	Event Type	Deaths	Date	Source
1	La Paz	Baja California Sur	Dam Failure (Hurricane Liza)	1000	1 October 1976	Vázquez et al., 1997 (based on Avante newspaper, La Paz, BCS, 7 October 1976). *Excelsior* and *El Universal* newspapers
2	Minatitlan	Colima	Regional Landslide event (Hurricane 15)	871	27 October 1959	Lugo y Flores, 1997 (personal communication based on *Excelsior* newspaper)
3	Sierra Norte de Puebla	Puebla	Regional landslide event (Tropical storm)	247	1999	SEPROCI, 1999 (personal communication)
4	Acapulco	Guerrero and Oaxaca	Regional Flash flood and landslides (Hurricane Pauline)	228	8–9 October 1997	CENAPRED, 2004
5	Tlalpujahua	Michoacan	Tailings dam failure associated with heavy rains	176	27 May 1937	Lugo y Flores, 1997 (personal communication based on *Excelsior* and *El Universal* newspapers)
6	Motozintla	Chiapas	Regional Landslide event	171	6–12 October 1998	*La Jornada* newspaper
7	San Pedro Atocpan	Distrito Federal	Regional Landslide event following cloud burst	150	4 June 1935	Lugo y Flores, 1997 (personal communication based on *Excelsior* and *El Universal* newspapers)
8	Valdivia	Chiapas	Regional Landslide event triggered by heavy rains	150	6–12 September 1998	*La Jornada* newspaper
9	Atentique	Jalisco	Regional Landslides, mudflows and floods caused by torrential rains	100	16 October 1955	OFDA/CRED Database Lugo y Flores, 1997 (personal communication based on *Excelsior* and *El Universal* newspapers)
10	Papantla	Veracruz	Regional Landslides, mudflows and floods triggered by heavy rains	60	6 October 1999	Desinventar database according to *La Jornada* newspaper

characterized by a highly dissected landscape, where contrasting lithological units enhance mass failure. Additionally, social-economic vulnerability of population is clearly expressed by poverty, lack of access to education, inadequate health conditions, deficient infrastructure, and scarce development and planning (Alcántara-Ayala, 2004).

4 Vulnerability and disasters

Landslide disaster risk can not be regarded only as a consequence of the likely occurrence of a physical phenomena, but also, as a result of the vulnerability of the exposed population. Vulnerability should be taken as a spatial-temporal dynamic process, which is pieced together within the historical dimension of development and socio-economic conditions of a particular community. It is strongly linked to the social processes that affect people's perception and coping strategies, and particularly it is determined by their fragility and lack of resilience. Therefore, and according the conceptual framework developed by Cannon (2003), vulnerability is conceived as a complex condition of people derived from the interactions among components such as initial well-being or base-line status; livelihood and its resilience; self-protection; social protection; and civil society, social and political networks and institutions, security.

The impact of disasters is undoubtedly determined by people's vulnerability. While natural hazards can be considered in terms of magnitude, frequency and probability, vulnerability is indeed a dynamic and heterogeneous process, whose complexity is expressed by the wide diversity of social, economic, politic and cultural conditions of societies. Under such account, disaster prevention could only be achieved if vulnerability is reduced.

Accordingly, disasters are not natural (Maskrey, 1993), it is unquestionably the condition of the individuals which determine the fact that a hazard could become a disaster (Cannon, 1994). Disasters result from two opposing processes: on one hand, the processes generating vulnerability, and on the other, physical exposure (Blaikie et al., 1994).

Expressly, although the portrayal of landslide disasters presented in this paper goes back to 1935, it was until the late eighties, specially after the 1985 Mexico City earthquake, that attention was given to disaster prevention nation-wide. As an immediate response to this event, the National Center for Disaster Prevention (CENAPRED) was established with the financial support of the Japan International Cooperation

Agency (JICA). During this period, geophysicists began to investigate natural hazards, particularly earthquakes and volcanic eruptions, whereas social scientist were the firsts to paid attention to the understanding of disasters as a whole complex system.

While ostensible, landslide – and other type of – hazards occurrence in Mexico is derived from the geological-geomorphological-climatic setting of the country, the incidence of disasters is governed by the lack of commitment to reduce vulnerability. The latter is enhanced by a series of vicious practices reinforced throughout the prevailing empowered political system.

In drawing the experiences of landslide disaster prevention in Mexico, certain key findings can be noted with respect to other natural hazards: (1) Attention to landsliding is relatively new and no systematic procedures have been developed; (2) Shortage of researchers devoted to investigate this type of hazards; (3) Limited resources for scientific developments; (4) A prevailing culture of reaction vs. prevention; (5) Multi-transdisciplinary and community participation efforts on risk management are inattentive and neglected; (6) Lack of development and growth of economically marginal communities; (7) High incidence of vulnerable groups in areas geomorphologically susceptible to mass movement processes; (8) Lack of planning at all levels (local, municipal, regional and national); (9) Lack of a lawful framework for evicting illegal squatters; (10) Uncoordinated civil protection activities; (11) Political and social boundaries which restrain the development, application and permanence of disaster prevention actions.

5 Conclusions

All the historical accounts of landslide disasters in Mexico during the period 1935–2006 suggest that on one hand, there is still a lack of structured knowledge on landsliding nationwide, and thus, on adequate strategies to mitigate and cope with their impact. Furthermore, on the other hand, it is clear that vulnerability has determined not only the past and actual landslide disaster effects, but will control the potential-future scenarios. Consequently, based on multi-transdisciplinary and community participation efforts, risk management and disaster prevention can be regarded as a critical challenge to be achieved in the forthcoming years. The latter should include a face devoted to reduce vulnerability, and building up a solid and genuine culture of disaster prevention.

The challenge still remains as achieving the full comprehension and implementation of disaster risk management as a multifaceted social process which looks towards reducing the current disaster risk levels and to the anticipation and control of future risk. The axis for short and long term management should be based on community planning in view of the fact that in any region, the mechanisms or linkages involved within such practice are dependant on the interest residents or local organized actors and institutional participants might have, besides building up the capability to take the required steps to reduce risk to an acceptable level. Likewise, disaster reduction must be initiated within the decision making framework in terms of policy and planning.

Conversely, from an international perspective, it is important not to be too critical in terms of only pointing the finger at "developing" countries like Mexico. Disaster prevention challenges should not be exclusively priorities for these nations, but for the so-called "developed" countries – including the USA – where certainly vulnerable groups also exist (minorities, indigenous communities, elderly people, women, etc.), and are highly susceptible to the impact of natural hazards. Paradoxically, despite of the huge worldwide impact of disasters in the last decades, no Millennium Development Goal has been established for disaster prevention, and the international politics agenda continues brushing aside such crucial issue; global commitment is urgently required.

Finally, I would like to draw to a close by quoting the accurate words of the former UN Secretary General, Kofi Annan in the framework of the 1999 General Assembly of the United Nations:

"…Confronting the horrors of war and natural disasters, the United Nations has long argued that prevention is better than cure; that we must address the root causes, not merely their symptoms… Today, no one disputes that prevention is better, and cheaper, than reacting to crises after the fact. Yet our political and organizational cultures and practices remain oriented far more towards reaction than prevention. In the words of the ancient proverb, it is difficult to find money for medicine, but easy to find it for a coffin…

The transition from a culture of reaction to a culture of prevention will not be easy, but the difficulty of our task does not make it any less imperative… Our solemn duty to future generations is to reduce these threats. We know what needs to be done. What is now needed is the foresight and political will to do it".

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References

Alcántara-Ayala, I.: Geomorphology, Natural Hazards, Vulnerability and Prevention of Natural Disasters in Developing Countries, Geomorphology, 47, 107–124, 2002.

Alcántara-Ayala, I.: Hazard assessment of rainfall induced landsliding in Mexico, Geomorphology, 61, 19–40, 2004.

Alger, C. and Brabb, E.: The development and application of a historical bibliography to assess landslide hazard in the United

States, in: The use of historical data in natural hazard assessments, edited by: Glade, T., Albini, P., and Frances, F., Advances of Technological and Natural Hazard Research, Kluwer, 2001.

Ayenew, T. and Barbieri, G.: Inventory of landslides and susceptibility mapping in the Dessie area, northern Ethiopia, Eng. Geol., 77, 1–2, 1–15, 2005.

Barkun, N.: Disaster and the Millenium, Yale Univ. Press, New Haven, 246 pp., 1974.

Berardino, P., Iodice, A., Pietranera, L., Rizzo, V., Costantini, M., and Franceschetti, G.: Use of differential SAR interferometry in monitoring and modelling large slope instability at Maratea (Basilicata, Italy), Eng. Geol., 68, 1–2, 31–51, 2003.

Bitrán, D.: Características e impacto socioeconómico de los principales desastres ocurridos en México en el período 1980–1999, publicación de la Dirección de Investigaciones del Centro Nacional de Prevención de Desastres (CENAPRED) de México y de la CEPAL, 107 pp., 2000.

Blaikie, P., Cannon, T., Davis, I., and Wisner, B.: At Risk: Natural Hazards, People's Vulnerability and Disasters, Routledge, London, 275 pp., 1994.

Brardinoni, F., Slaymaker, O., and Hassan, M. A.: Landslide inventory in a rugged forested watershed: A comparison between air-photo and field survey data, Geomorphology, 54, 3–4, 179–196, 2003.

Calcaterra, D. and Parise, M.: The contribution of historical information in the assessment of landslide hazard, in: The use of historical data in natural hazard assessments, edited by: Glade, T., Albini, P., and Frances, F., Advances of Technological and Natural Hazard Research, Kluwer, 201–215, 2001.

Cannon, T.: Vulnerability Analysis and the Explanation of 'Natural' Disasters, in: Disasters, Development and Environment, edited by: Varley, A., John Wiley and Sons Ltd., 13–30, 1994.

Cannon, T.: Vulnerability Analysis, Livelihoods and Disasters Components and variables of vulnerability: modelling and analysis for disaster risk management, Indicators for Disaster Risk Management, OPERATION ATN/JF-7907-RG, Inter-American, 2003.

Development Bank, Instituto de Estudios Ambientales, Universidad nacional de Colombia (Manizales), 25 pp., 2003.

Corona-Esquivel, R., Mancilla-Figueroa, H. M., Chávez-Galván, R., and Lugo-Hubp, J.: El desastre de Minatitlán, Colima, México, del martes 27 de octubre de 1959, in: Desastres naturales en América Latina, edited by: Lugo-Hubp, J. and Inbar, M., Fondo de Cultura Económica, México, 413–427, 2002.

Chau, K. T., Wong, R. H. C, Liu, J., and Lee, C. F.: Rockfall Hazard Analysis for Hong Kong Based on Rockfall Inventory, Rock Mech. Rock Eng., 36, 5, 383–408, 2003.

Chau, K. T., Wong, W. Y., Fong, E. L., Chan, L. C. P., Sze, Y. L., and Fung, M. K.: Landslide hazard analysis for Hong Kong using landslide inventory and GIS, Comput. Geosci., 30, 4, 429–443, 2004.

Davis, L.: Natural disasters: revised edition, Facts On File, Inc., New York, USA, 420 pp., 2002.

Duman, T. Y., Keçer, M., Dogcaronan, A., Ates, S., Durmaz, S., Çan, T., and Emre, Ö.: Landslide inventory of northwestern Anatolia, Turkey, Eng. Geol., 77, 1–2, 99–114, 2005.

Evans, S. G. and Alcántara-Ayala, I.: Disasters resulting from landslides, snow avalanches, and geotechnical failures in North America (Canada, United States, and Mexico) 1841–2006: A first assessment, in: Landslides in North America, edited by: Turner, A. K. and Schuster, R. L., Association of Engineering Geologists, Special Publication 22, 3–23, 2007.

Glade, T.: Landslide hazard assessment and historical landslide data – an inseparable couple?, in: The use of historical data in natural hazard assessments, edited by: Glade, T., Albini, P., and Frances, F., Advances of Technological and Natural Hazard Research, Kluwer, 153–169, 2001.

Glade, T., Albini, P., and Frances, F. (Eds.): The use of historical data in natural hazard assessments, Advances of Technological and Natural Hazard Research, Kluwer, 220 pp., 2001.

Glade, T., Anderson, M., and Crozier, M. J. (Eds.): Landslide hazard and risk, Wiley, 803 pp., 2005.

Guzzetti, F., Cipolla, F., Sebastiani, C., Galli, M., Salvati, P., Cardinali, M., and Reichenbach, P.: Landslides triggered by the 23 November 2000 rainfall event in the Imperia Province, Western Liguria, Italy, Eng. Geol., 73, 3–4, 229–245, 2004.

Ibsen, M. L. and Brundsen, D.: The nature, use and problems of historical archives for the temporal ocurrence of landslides, with specific reference to the south coast of Britain, Ventnor, Isle of Wight, Geomorphology, 15, 241–258, 1995.

Ibsen, M. L, Brundsen, D., Lee, M., and Moore, R.: The Validity of Temporal Archive Records for Geomorphological Processes, Quaestiones Geographicae, 4, 79–92, 1995.

Keefer, D. K.: Investigating landslides caused by earthquakes – A historical revie, Surv. Geophys., 23, 6, 473–510, 2002.

Lugo, J., Zamorano, J. J., Capra, L., Inbar, M., and Alcántara-Ayala, I.: Los procesos de remoción en masa en la Sierra Norte de Puebla, octubre de 1999, causas y efectos, Revista Mexicana de Ciencias Geológicas, Instituto de Geología, 22, 2, 212–228, 2005.

Mahdavifar, M. R., Solaymani, S., and Jafari, M. K.: Landslides triggered by the Avaj, Iran earthquake of June 22, 2002, Eng. Geol., 86, 2–3, 166–182, 2006.

Malamud, B. D., Turcotte, D. L., Guzzetti, F., and Reichenbach, P.: Landslides, earthquakes and erosion, Earth Planet. Sci. Lett., 229, 1–2, 45–59, 2004a.

Malamud, B. D., Turcotte, D. L., Guzzetti, F., and Reichenbach, P.: Landslide inventories and their statistical properties, Earth Surf. Proc. Land., 29, 6, 687–711, doi:10.1002/esp.1064, 2004b.

Maskrey, A.: Los Desastres no son Naturales, Tercer Mundo Editores, Santa Fé de Bogotá, Colombia, 1993.

Nichol, J. and Wong, M. S.: Satellite remote sensing for detailed landslide inventories using change detection and image fusion, Int. J. Rem. Sens., 26, 9, 1913–1926, 2005.

Padilla, R.: El huracán del 59, historia del desastre y reconstrucción de Minatitlán, Colima, Colima, Universidad de Colima, 2006.

Parise, M.: Landslide mapping techniques and their use in the assessment of the landslide hazard, Phys. Chem. Earth, 26, 9., 697–703, 2000.

Van Den Eeckhaut, M., Nyssen, J., Moeyersons, J., van Beek, L. P. H., Vandekerckhove, L., Poesen, J., Verstraeten, G., and Vanacker, V.: Use of LIDAR-derived images for mapping old landslides under forest, Earth Surf. Proc. Land., 32, 5, 754–769, 2007.

Van Westen, C. J., van Asch, T. W. J., and Soeters, R.: Landslide hazard and risk zonation - Why is it still so difficult?, B. Eng. Geol. Environ., 65, 2, 167–184, 2006.

Vazquez, M. T., Dominguez, R., Fuentes, O., and Maza, J. A.:

Flash floods in Mexico, in: Twenty Years Later What Have We Learned Since the Big Thompson Flood, edited by: Gruntfest, E., Proceedings of the Meeting held in Fort Collins, Colorado, July 10–13, 1996, Natural Hazards Research and Applications Information Center, Boulder, Colorado, Special Publication No. 33, 153–160, 1997.

Wills, C. J. and McCrink, T. P.: Comparing landslide inventories: The map depends on the method, Environ. Eng. Geosci., 8, 4, 279–293, 2002.