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Advancing Culture of Living with Landslides

Volume 4 Diversity of Landslide Forms

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Hiroshima landslide disasters in August 2014, Hiroshima, Japan (PASCO Corporation—Kokusai Kogyo Co., Ltd. All Rights Reserved)

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Foreword By Irina Bokova

Every year, disasters induced by natural hazards affect millions of people across the world. The loss of life is tragic, impacting on communities for the long term.

The costs are also economic, as disasters are responsible for estimated annual economic losses of around USD 300 billion. With the rising pressures of climate change, overpopulation, and urbanization, we can expect costs to increase ever more.

We cannot prevent disasters but we can prepare for them better. This is the importance of the *International Consortium on Landslides*, supported actively by UNESCO, to advance research and build capacities for mitigating the risks of landslides. Led by Prof. Kyoji Sassa, the Consortium has become a success story of international scientific cooperation at a time when this has never been so vital.

This is especially important as the world implements the *2030 Agenda for Sustainable Development* and the Paris Agreement on Climate Change, as well as the *Sendai Framework for Disaster Risk Reduction 2015–2030*—adopted in Sendai, Japan, to assess global progress on disaster risk reduction and set the priority actions.

The International Strategy for *Disaster Risk Reduction—International Consortium on Landslides Sendai Partnerships 2015–2025* is the key outcome relating to landslides from the 3rd World Conference on Disaster Risk Reduction, held in Sendai. On this basis, every member of the *International Consortium of Landslides* is redoubling efforts to understand, foresee, and reduce landslide disaster risk across the world.

Led by the Consortium, the Landslide Forum is a triennial milestone event that brings together scientists, engineers, practitioners, and policy makers from across the world—all working in the area of landslide technology, landslide disaster investigation, and landslide remediation. Meeting in Slovenia, the 4th Landslide Forum will explore the theme, "Landslide Research and Risk Reduction for Advancing Culture of Living with Natural Hazards", focusing on the multidisciplinary implementation of the Sendai Framework to build a global culture of resilient communities.

Against this backdrop, this report includes state-of-the-art research on landslides, integrating knowledge on multiple aspects of such hazards and highlighting good practices and recommendations on reducing risks. Today, more than ever, we need sharper research and stronger scientific cooperation. In this spirit, I thank all of the contributors to this publication and I pledge UNESCO's continuing support to deepening partnerships for innovation and resilience in societies across the world.

January 2017

Irina Bokova
Director General of UNESCO

Foreword By Robert Glasser

Landslides are a serious geological hazard. Among the host of natural triggers are intense rainfall, flooding, earthquakes or volcanic eruption, and coastal erosion caused by storms that are all too often tied to the El Niño phenomenon. Human triggers including deforestation, irrigation or pipe leakage, and mining spoil piles, or stream and ocean current alteration can also spark landslides.

Landslides occur worldwide but certain regions are particularly susceptible. The UN's Food and Agriculture Organization underlines that steep terrain, vulnerable soils, heavy rainfall, and earthquake activity make large parts of Asia highly susceptible to landslides. Other hotspots include Central, South, and Northwestern America.

Landslides have devastating impact. They can generate tsunamis, for example. They can bring high economic costs, although estimating losses is difficult, particularly so when it comes to indirect losses. The latter are often confused with losses due to earthquakes or flooding.

Globally, landslides cause hundreds of billions of dollars in damages and hundreds of thousands of deaths and injuries each year. In the US alone, it has been estimated that landslides cause in excess of US$1 billion in damages on average per year, though that is considered a conservative figure and the real level could be at least double.

Given this, it is important to understand the science of landslides: why they occur, what factors trigger them, the geology associated with them, and where they are likely to happen.

Geological investigations, good engineering practices, and effective enforcement of land use management regulations can reduce landslide hazards. Early warning systems can also be very effective, with the integration between ground-based and satellite data in landslide mapping essential to identify landslide-prone areas.

Given that human activities can be a contributing factor in causing landslides, there are a host of measures that can help to reduce risks, and losses if they do occur. Methods to avoid or mitigate landslides range from better building codes and standards in engineering of new construction and infrastructure, to better land use and proper planned alteration of drainage patterns, as well as tackling lingering risks on old landslide sites.

Understanding the interrelationships between earth surface processes, ecological systems, and human activities is the key to reducing landslides disaster risks.

The Sendai Framework for Disaster Risk Reduction, a 15-year international agreement adopted in March 2015, calls for more dedicated action on tackling underlying disaster risk drivers. It points to factors such as the consequences of poverty and inequality, climate change and variability, unplanned and rapid urbanization, poor land management, and compounding factors such as demographic change, weak institutional arrangements, and non-risk-informed policies. It also flags a lack of regulation and incentives for private disaster risk reduction investment, complex supply chains, limited availability of technology, and unsustainable uses of natural resources, declining ecosystems, pandemics and epidemics.

The Sendai Framework also calls for better risk-informed sectoral laws and regulations, including those addressing land use and urban planning, building codes, environmental and

resource management and health and safety standards, and underlines that they should be updated, where needed, to ensure an adequate focus on disaster risk management.

The UN Office for Disaster Risk Reduction (UNISDR) has an important role in reinforcing a culture of prevention and preparedness in relevant stakeholders. This is done by supporting the development of standards by experts and technical organizations, advocacy initiatives, and the dissemination of disaster risk information, policies, and practices. UNISDR also provides education and training on disaster risk reduction through affiliated organizations, and supports countries, including through national platforms for disaster risk reduction or their equivalent, in the development of national plans and monitoring trends and patterns in disaster risk, loss, and impacts.

The International Consortium on Landslides (ICL) hosts the Sendai Partnerships 2015–2025 for the global promotion of understanding and reducing landslide disaster risk. This is part of 2015–2025, a voluntary commitment made at the Third UN World Conference on Disaster Risk Reduction, held in 2015 in Sendai, Japan, where the international community adopted the Sendai Framework.

The Sendai Partnerships will help to provide practical solutions and tools, education and capacity building, and communication and public outreach to reduce landslides risks. As such, they will contribute to the implementation of the goals and targets of the Sendai Framework, particularly on understanding disaster risks including vulnerability and exposure to integrated landslide-tsunami risk.

The work done by the Sendai Partnerships can be of value to many stakeholders including civil protection, planning, development and transportation authorities, utility managers, agricultural and forest agencies, and the scientific community.

UNISDR fully support the work of the Sendai Partnerships and the community of practice on landslides risks, and welcomes the 4th World Landslide Forum to be held in 2017 in Slovenia, which aims to strengthen intergovernmental networks and the international programme on landslides.

Robert Glasser
Special Representative of the Secretary-General
for Disaster Risk Reduction and head of UNISDR

Preface

The term “landslide” describes a wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, debris, soil, artificial fill, or a combination of these.

This includes a wide variety of phenomena, from simple fall of rock blocks from vertical faces, through topples, to landslides that are dominated by sliding motion and those dominated by flows of soil and/or rock. Landslides are strongly correlated with other types of natural hazards, such as floods, droughts, wildfires, earthquakes, tsunamis, and volcanoes, and are often involved in cascading events of multi-hazard disasters.

Climate change, increased susceptibility of surface soil to instability, anthropogenic activities, growing urbanisation, uncontrolled land-use and increased vulnerability of population and infrastructure, contribute to the growing landslide risk. In the Thematic Strategy for Soil Protection (COM232/2006), landslides are considered one of the main threats to European soils. The societal and economic impact of landslide risk is difficult to be assessed and it is underestimated since a relevant part of related damage is attributed to other natural hazards, in multi-hazard chains (i.e. seismically induced failures, rainfall induced debris flows, lahars and rock avalanches associated to volcanism).

The various types of landslides can be differentiated by the kinds of material involved and the mode of movement. Five main different types of movements have been discerned (Cruden and Varnes 1996, Hungr et al. 2014), which are: falls, topples, slides, spreads, or flows.

Landslides are classified also according to the type of material involved. According to Cruden and Varnes (1996) material can be rock or soil; the latter is described as earth if mainly composed of sand-sized or finer particles and debris if composed of coarser fragments. Hungr et al., (2014) proposed a new classification of material in order to provide compatibility with accepted geotechnical and geological terminology of rocks and soils.

The proposed list of material types is: “rock,” “clay,” “mud,” “silt,” “sand,” “gravel,” “boulders,” “debris,” “peat,” and “ice”.

Landslides are thus described using two terms that refer respectively to material and movement.

Landslides vary greatly in size. At the largest scale, a single landslide can involve up to some cubic kilometer of rock and soils. At the other end of the scale, a small boulder has the potential to cause loss of life if it strikes an individual, or to cause mass fatalities if it, for example, induces a train to derail. In general, the potential to cause loss scales with size of the landslide, largely because of the scaling of the kinetic energy and the affected area.

Landslide can be distinguished also on the basis of the rate of movement and according to Cruden and Varnes (1996) seven classes of velocity can be identified, from extremely slow to extremely rapid. Velocity is an important parameter, strongly related to the degree of damage to the elements at risks.

Landslide occurrence varies according to different causes such as topographic profile, geology, tectonic history, weathering and erosional history, and land use.

However, landslides are usually considered to have only one trigger (Varnes 1978). A trigger is an external stimulus such as an intense rainfall event, an earthquake, a volcanic

eruption, a storm wave, or rapid stream erosion that causes a near-immediate response in the form of a landslide by rapidly increasing the stresses or strains and reducing the strength of the slope-forming materials (Wieczorek 1996). Rainfall is one of the most important triggering factor of landslides. The type of landslide produced in this case depends largely upon the frequency and magnitude, in terms of intensity and/or duration, of the rainfall events (Fukuoka 1980, Wieczorek 1987). Both shallow and deep-seated landslides can be triggered by rainfall, with different frequencies, both in time and space, and under the effects of different types of storms.

Earthquakes can trigger different types of landslides in different geological, topographic and climatic conditions and the dimension of landslides can vary from small rock falls to giant landslides. Earthquakes in steep landslide-prone areas largely increase the likelihood that landslides will occur, due to the ground shaking alone, liquefaction of susceptible sediments, or shaking-caused dilation of soil materials, which allows rapid infiltration of water. Ground shaking can also cause rock falls or rock topples due to loosening of rocks.

Landslides and other types of natural hazards such as floods, droughts, wildfires, tsunamis, and volcanoes can be strongly correlated to the so-called cascade effects. For example, landslides can cause flooding by forming landslide dams that block valleys and stream channels, allowing large amounts of water to back up. On the contrary, droughts and fires can produce bare soils (or lands with reduced vegetal protection) exposed to the direct consequences of rainfalls and weathering phenomena.

This volume of WLF4 includes recent research achievements related to different landslide types in terms of typology, material and triggering factors. This volume will include also research outcomes made on the relationship between landslides and other natural hazards.

In particular, this volume has been organized in five chapters that correspond to the following sessions:

Session 4.1 – Earthquake-induced landslides;

Session 4.2 – Rainfall-induced landslides;

Session 4.3 – Rapid landslides: debris flows, mudflows, rapid debris-slides;

Session 4.4 – Landslides in rocks and complex landslides: rock topples, rock falls, rock slides, complex landslides;

Session 4.5 – Landslides and other natural hazards: floods, droughts, wildfires, tsunamis, and volcanoes.

Florence, Italy Nicola Casagli

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