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Advancing Culture of Living with Landslides

Volume 5 Landslides in Different Environments

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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.

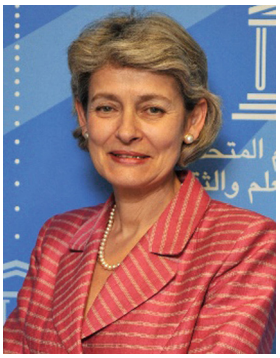
This is especially important as the world implements the *2030 Agenda for Sustainable Development* and the Paris Agreement on Climate Change, as well as the *Sendai Framework for Disaster Risk Reduction 2015–2030*—adopted in Sendai, Japan, to assess global progress on disaster risk reduction and set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

In this Volume 5, we present four different sessions: Landslide Interactions with the Built Environment, Landslides in Natural Environment, Landslides and Water, Landslides as Environmental Change Proxies—Looking at the Past. The main objective is to draw attention to the different types of landslides with respect to communities, infrastructure and cultural heritage. Landslides in the natural environment are also covered, including all forms of aquatic environments. Recent progress in dating techniques has greatly improved the ability to determine the age of landslides allowing us to address the challenge of relating established landslide chronologies to regional paleoenvironmental changes (e.g. paleoseismic events, deglaciation, climatic changes, human-induced deforestation). The relations between climatological (and climate change) and geomorphological zones or settings are important in that they determine the dominant landslide type and the associated triggering mechanisms.

Research into landslides that are causally related to precipitation has recently been discussed in relation to climate change. Climate change may be a triggering effect for modifications to climatic parameters (weather), which are difficult to quantify and which play an important (or even key) role in the emergence of individual types of slope movement. Conditions may be different from region to region. For instance, regelation processes are of key importance for rock falls, increases in temperature for shallow slope movements in periglacial zones and increases in the sea level for coastal areas. Aridization of climate in certain areas can cause an increased frequency of fires and subsequently increase susceptibility to the formation of debris flows. Nevertheless, it is generally accepted that mountain environments are very susceptible to climatic change. The impact of changes in weather that results from climatic change, on slope stability must be studied and understood in the context of different geomorphological conditions (e.g. fluvial, glacial or periglacial types of relief) and geotechnical conditions (e.g. rock massifs, weathered mantle), as well as adaptation strategies.

However, in mountainous as well as tectonically active areas we often find a combination of different impacts generating conditions favourable to the development of slope deformations. There are steep slopes formed by intensive erosion, tectonically crushed zones, a higher degree of seismicity, and anthropogenic impacts can also be important (road construction, deforestation, agriculture, etc.) due to an increase in population. While precipitation may be the trigger, the contribution of other factors may also be important albeit difficult to quantify as their influence may be variable with time.

A clear understanding of the influence of hydraulic conditions on slope instability is necessary when water is the trigger for such movements. This may be achieved by using precipitation triggers as a proxy for the more direct factors related to the condition of the soil with respect to water. Alternatively, where a very clear, and generally straightforward, ground model exists it may be possible to use directly measured soil-moisture parameters to understand the triggering processes.

Kinematics of movements (for instance continuous movement with acceleration, seasonal movements, etc.) must also be taken into consideration. In terms of climatic factors, we cannot neglect temperature as it affects, for example, pore pressure through evapotranspiration and phase changes of precipitation.

This Volume 5 presents a wide range of papers that will make a substantial contribution to the state-of-the-art, aiding researchers in taking forward and increasing our knowledge and understanding of the effect of landslides on different environments. This is particularly the case in those environments in which humans and their infrastructure form an important part of that environment and thus comprise a significant part of the elements that are at risk from landslide hazards.

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