Guideline

On Integrating Climate Change Projection Into Landslide Risk Assessments & Mapping

At The River Basin Level

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ACKNOWLEDGEMENTS

The Guidelines was commissioned through a partnership between the Institute for Global Environmental Strategies, CTI Engineering International Co., Ltd, Asian Disaster Preparedness Center and The ASEAN Secretariat. It was made possible by financial support from The Government of Japan through the Japan-ASEAN Integration Fund (JAIF).

The guideline was authored by the project team, under the oversight of Co-Chairs of the ACDM Working Group on Prevention and Mitigation and the ASEAN Secretariat. The team included Dr Prabhakar Sivapuram Venkata Rama Krishna (Socio-Economic Assessment Specialist), Dr Binaya Raj Shivakoti (Capacity Building Specialist), Ms Anggraini Dewi (Risk Assessment Specialist), N.M.S.I Arambepola (Landslide Risk Management Expert), Dr Rendy Dwi Kartiko (Landslide Hazard Mapping Expert), Mr Susantha Jayasinghe (Climate Change Modeling Specialist), Dr Senaka Basnayake (Climate Change Adaptation Specialist), Dr Peeranan Towashiraporn (Risk Assessment Advisor) and Ms Pimvadee Keaokiriya (ASEAN DRR-CCA Program Manager).

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FOREWORD

Southeast Asian countries are diverse in their socio-economic and cultural profiles and yet share some common elements that make the region one of the world's most diverse. Country economies have developed rapidly in the past decade and are projected to continue this accelerated growth. Rapid economic development has led to significant achievements in socio-economic development. However, this rapidly changing socio-economic landscape in Southeast Asia is also generating climate change, disaster risks and vulnerabilities. Countries in the region are especially vulnerable to floods, droughts, typhoons, and landslides. Some of the world's top ten countries most affected by disasters are located in the region. For example, Myanmar reported the largest percentage of losses from extreme weather-related events (0.8% of GDP), followed by the Philippines (0.6%), Vietnam (0.5%), and Thailand (0.9%). The Global Climate Risk Index lists Myanmar, Philippines, and Vietnam in the top ten most affected countries by extreme weather events.

Recognizing the importance of addressing climate change and disaster risks, countries have implemented overarching disaster risk reduction and climate change adaptation plans, regulations and laws at regional and national levels and are rapidly progressing towards localizing them in specific sectors. One important element that still requires significant progress is integrating climate change projections into disaster risk assessments; support and enhance related knowledge and skills at all levels so that climate-proof risk assessments are implemented, shared and implemented. These forward-looking assessments will equip planners and decision-makers to manage rapidly the changing risk profiles due to climate change and related uncertainties.

The project captured the essence of these regional climate-related needs and has developed two set of guidelines designed to assist relevant agencies and sectors to plan and prepare for climate induced risks. This is based on the implementation in pilot river basins in Lao PDR and Myanmar, through series of interactive hands-on training, data collection, field exercises and surveys. – addressing on-the-ground disaster risk planning challenges and potential climate change impact, also taking into account the existing institutional set up, human resources, data capacities and limitations that are applicable to Southeast Asia countries. These guidelines and their tools are recommended for beginners and middle-level experts in the field of disaster management, natural resources and environment, water resource planners, climate change adaptation, urban planners and public works. They are unique as that they are targeted at the watershed level, multi-disciplinary in nature, and espouse principles of integrated risk assessment and integrated planning.

Last but not least, we congratulate the RBPs and host countries, national counterparts and consultant teams from IGES, CTII and ADPC for their valuable efforts. These guidelines are living documents and are expected to be revised at regular intervals by incorporating new and emerging knowledge with regards to climate change and disaster risk reduction. We highly recommend that all relevant national and regional stakeholders promote and disseminate these guidelines to foster their adoption to the location-specific contexts in ASEAN region demands.

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MESSAGE FROM MISSION OF JAPAN

Increasing climate change impacts and more frequent natural disaster events in these years have led to growing awareness of the need for accelerating climate change adaptation (CCA). Southeast Asia is said to be the most disaster-ridden region in the world, and is no longer free from unprecedented challenges caused by global climate change.

Because of geographical, topographical and meteorological conditions, Japan is also prone to natural disasters such as torrential rain, floods, landslides, earthquakes and tsunami. As a disaster-prone country, Japan is keen to support ASEAN's efforts to enhance regional mechanisms under the framework of the ASEAN Agreement on Disaster Management and Emergency Response (AADMER). In this regard, the Government of Japan is proud to support the development of guidelines for flood and landslide risks through the Japan-ASEAN Integration Fund (JAIF), which has played a vital role in Japan's cooperation to support ASEAN's community-building and integration efforts.

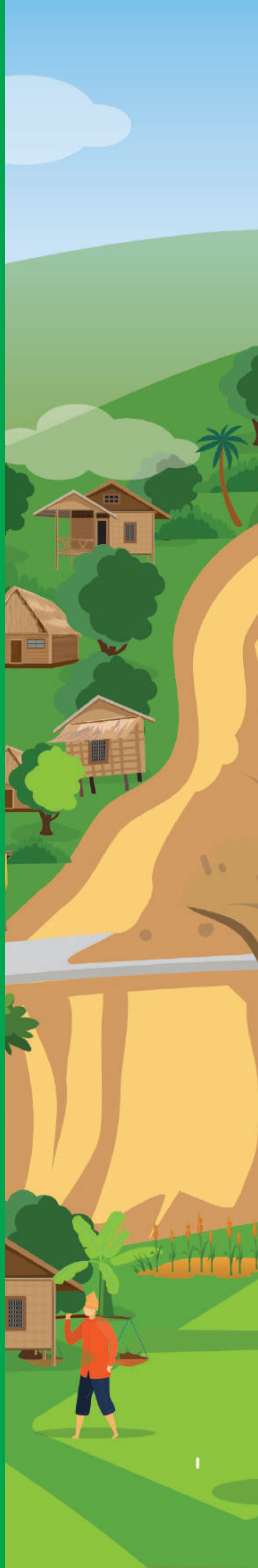
The Guidelines for flood and landslide risks were developed with the intention to assist ASEAN Member States in conducting flood and landslide risk assessment. The Guidelines contribute to mapping of flood and landslide risks by integrating climate change impacts at river basin level. It is expected that flood and landslide risks as well as associated vulnerabilities to extreme hydrological events are identified more easily by conducting the Guidelines.

I am confident that the risk assessment methodology presented in these Guidelines will be useful for planning and appropriate decision-making.

Last but not least, I wish to convey my gratitude to everybody who was involved in this valuable project. We are committed to further enhancing Japan's cooperation with ASEAN through the activities of JAIF.

H.E CHIBA Akira

Ambassador of Japan to ASEAN



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(Scan QR code to download)

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(Scan QR code to download)

Scan QR code for full report and maps

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GLOSSARY

Terms	Definitions
Disaster	A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with exposure, vulnerability and capacity conditions, leading to one or more of the following losses and impacts: human, material, economic and environmental.
Disaster risk	The potential loss of life or injury, or the damage or destruction of assets that could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.
Risk	The probability of harmful consequences, or expected losses (death, injury, property, livelihoods, economic activity or environment) resulting from interactions between natural, human-induced or human-made hazards and vulnerable conditions.
Risk assessment	A qualitative and/or quantitative approach to determine the nature and extent of disaster risk by analyzing potential hazards and evaluating existing exposure and vulnerability conditions that together could harm people, property, services, livelihoods and the environment on which they depend.
Disaster risk management	The application of disaster risk reduction strategies, policies, and actions to prevent new disaster risk, reduce existing disaster risk and manage residual risk.
Element at-risk	Elements such as assets, population and environmental features that are exposed to landslides due to various physical/structural, social, economic, and environmental factors.
Exposure	Present conditions for people, infrastructure, housing, production capacity and other tangible human assets located in hazard-prone areas.
Hazard	A natural or human caused process, phenomenon, activity or incident that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.
Structural and non-structural measures	Structural measures are defined as physical construction to reduce or avoid possible hazard impacts, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems. Non-structural measures are those not involving physical construction that use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, and training and education.
Vulnerability	Conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an individual, community, assets or systems to hazard impacts.

Terms	Definitions
Capacity	A combination of the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience.
Landslide	Slides such as rockslides, debris flows, snow avalanches, and those rainfall and earthquake-induced that are characterized by rapid mass movement, in addition to slow moving slides that may have significant economic consequences for construction and infrastructure. In these guidelines, the word 'landslide' implies both existing or known slides and potential slides that a slide expert can reasonably predict based on relevant geology, geometry and slope forming processes.
Landslide inventory	Landslide location, classification, volume, activity and occurrence date.
Landslide susceptibility	A quantitative or qualitative assessment of the classification, volume (or area) and spatial distribution of landslides that exist or may occur in an area. Susceptibility may also include a description of the velocity and intensity of existing or potential landslides.
Likelihood	A qualitative description of landslide probability or frequency.
Probability	A measure of degree of certainty with a value between zero (impossibility) and 1.0 (certainty) that estimates occurrence likelihood, or the magnitude, of an uncertain future event.
Qualitative risk analysis	An analysis that uses word form, descriptive or numeric rating scales to describe the likelihood and magnitude of potential consequences.
Quantitative risk analysis	An analysis on the numerical value of a risk based on probability, vulnerability and consequences.
Climate change	Changes in climate that are attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. (Source: United Nations Framework Convention on Climate Change/UNFCCC)
Zoning	The division of land into homogeneous areas or domains and the ranking of those areas or domains according to actual or potential landslide susceptibility, hazard or risk degree.

ACRONYMS AND ABBREVIATIONS

Abbreviations	Description
A:	
AADMER	Agreement on Disaster Management and Emergency Response
ACDM	ASEAN Committee on Disaster Management
ADB	Asian Development Bank
ADPC	The Asian Disaster Preparedness Center
AMS	ASEAN Member States
APHRODITE	The Asian Precipitation Highly-Resolved Observational Data Integration Towards Evaluation
B:	
BAU:	Business-as-usual
C:	
C	Contrast Value
CBLRRM	Community-based Landslide Risk Reduction and Management
CBPLRMS	Community based Participatory Landslide Risk Management Strategy
CCA	Climate Change Adaptation
CHG	Climate Hazard Group
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station
CMIP5	The Coupled Model Inter-comparison Project Phase 5
CN	Concept Note
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
D:	
DDR	Disaster Risk Reduction
DEM	Digital Elevation Model
E:	
ENSO	The El Nino Southern Oscillation
G:	
GCMs	Global Circulation Models
GCMs	Global Climate Models
GHG	Greenhouse Gas
GIS	Geographic Information System
I:	
IDB	Inter-American Development Bank
IGES	The Institute for Global Environmental Strategies
IOD	The Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization

Abbreviations	Description
J:	
JAIF	Japan ASEAN Integration Fund
JICA	Japan International Cooperation Agency
L:	
LVSs:	Landslide Vulnerably Scores
M:	
M-BRACE	Mekong Building Climate Resilience in Asian Cities program
MJO	The Madden-Julian Oscillation
MRI/JMA	Meteorological Research Institute of the Japan Meteorological Agency
N:	
NDMO	National Disaster Management Organization
NEX	The NASA Earth Exchange
P:	
PRA	Participatory Rural Appraisal
R:	
RBP	River basin pilot
RCPs	Representative Concentration Pathways
RIHN	Research Institute for Humanity and Nature
S:	
SALT	Sloping Agriculture Land Technology
SFDRR	Sendai Framework for Disaster Risk Reduction
SRTM	Shuttle Radar Topographic Mission
SRTM	Shuttle Radar Topographic Mission
SSPs	Socio-economic Scenarios/Shared Socio-economic Pathways
T:	
TGICA	Task Group on Data and Scenario Support for Impact and Climate Assessment
U:	
UNDRR	United Nations Office for Disaster Risk Reduction
UTM	Universal Transverse Mercator
V:	
VCA	Vulnerability and Capacity Assessment
VCAI	Vulnerability Capacity Assessment Index
W:	
W-/+	Negative/Positive Weight
WOE	Weight of Evidence


Photo: Shutterstock / Bill MacLachlan

1 INTRODUCTION

1.1. Landslide risk management in ASEAN Member States

Landslides are a geological process common across ASEAN Member States (AMS). They are often triggered by earthquakes, unstable geological conditions, and/or rainfall. Human development activities on fragile slopes are also responsible for landslides. Landslide numbers are on the rise mainly due to increasing rainfall intensity. Landslides can co-occur at the same time as floods during, or in the aftermath, of heavy or prolonged rainfall events. Seven out of ten ASEAN Member States (excepting Brunei, Cambodia, and Singapore) were affected by flood and landslides during the 2015-2016 El Nino, with impact and severity highest in Indonesia, Myanmar, and Vietnam. Increasing widespread landslide incidences are a new challenge to AMS, as in 2018 when the majority of Lao PDR, as well as Myanmar, experienced heavy flooding and landslides that exceeded country response capacity. Another example is the devastating floods and landslides in June-August 2015 in Myanmar. Many parts of the country, and in particular its mountainous regions such as Chin State, were affected by devastating landslides, cyclones and floods. These calamities significantly damaged lives and property, especially in the Chin State capital of Hakha.

Climate change is considered a key factor behind the changing intensity, frequency and timing of rainfall events. A worldwide review of global rainfall data by Westra, Alexander, and Zwiers (2012), concludes "rainfall extremes are increasing on average globally." At both the global and Asia and the Pacific regional scale, extreme hydro-meteorological events are the dominant cause of disasters (UNESCAP 2017). Extreme hydrometeorological disasters accounted for 72 percent of the frequency of extreme natural disasters recorded during 1971– 2010 in Asia and the Pacific and accounted for more than half of the increase in frequency of intense hydrometeorological disasters recorded globally from 1971–1980 and 2001–2010 (Thomas et al., 2013). This rise in extreme hydrological events in turn compounds landslide risk levels.

Human induced factors such as dense settlements, deforestation, and migration to, and poorly planned development in, high exposure areas also contribute to disaster risks. When human and climate change induced risks combine, the consequences are often very severe. Existing approaches to landslide risk management therefore need to be revisited to account for these climate and human induced changes and weak disaster risk reduction (DRR) and climate change adaptation (CCA) capacity.

1.2. AMS landslide risk assessment and mapping challenges and capacity gaps

Many ASEAN Member States are experiencing increased landslide risk due to climate change and high human population and activity near fragile high exposure areas. Appropriate mitigation measures suffer from inadequate hydro-metrological observation (rainfall, temperature, water level) information due to lack of adequate monitoring and measuring instruments and limited institutional and human resources capacity to install enough monitoring stations. Landslides are localized in nature. Addressing them involves a complex mix of physical (geology, land use, topography, soil, rainfall, drainage), social and cultural factors. Landslide protection infrastructure often cannot be built in AMS areas with high human density due to economic or environmental constraints. Additionally, it often is not possible to evacuate people from high risk areas due to societal reasons, land scarcity and prohibitive land development costs. Proposed risk management options should be reliable, cost effective and endorsed by policymakers.

Along with the above-mentioned factors, assessments on future landslide risk must be integrated into long-term climate change predictions that include precipitation change patterns. This will ensure greater knowledge for building the most appropriate risk management options.

With the increasing frequency of landslides in many ASEAN countries, the importance of risk assessment for improving risk knowledge is also growing. However, the perception of landslide disaster risk as a dynamic concept, which is an essential factor in delineating the probable landslide risk in a specific area event, is yet to be well integrated into disaster risk reduction processes. ASEAN countries also need to recognize that landslide disaster is not a random event but instead results from a set of incremental actions that lead to landslide risk accumulation. This understanding, however, may not necessarily be predominant in government agencies, development practitioners and the general public. Development of a culture for undertaking cost effective reliable long-term landslide risk management interventions, as opposed to short term fixes, to build community resilience is essential.

ASEAN Member States face a number of landslide risk management challenges in the changing context of recurrent extreme hydrological events and expected climate change impact intensification. One of the prominent challenges AMS agencies tasked with landslide risk reduction face is inadequate understanding of the nature and scale of the risks of both current landslides and those that may occur under future climate change scenarios. Key questions to be addressed in this context include:

- What will be the scale and extent of future landslides, especially those caused by human induced global warming? How can downscaled climate change projections be used to assess climate change impacts at the local level?
- Given the new challenges posed by climate change, how can the decision-making capacity of agencies involved in landslide risk management be improved?
- What kinds of disaster preparedness and planning will be necessary to address multiple landslide incidences, and to minimize risks? How can landslide risk management be adopted and improved to minimize future risks?
- How will huge capacity gaps in disaster risk and hazard mapping technology knowledge be addressed?

Building a disaster resilient ASEAN community may require a significant overhaul of existing disaster risk management systems. Agencies tasked with disaster risk management cannot make appropriate decisions without reliable knowledge on risk level that is the foundation of a flexible and resilient integrated landslide risk management scale plan. These decisions are closely associated with resource allocation reinforcement, hydro-meteorological and landslide monitoring system upgrading and expansion, geological assessment and landslide prediction capacity improvement, structural and non-structural design measures, and revitalizing preparedness and response systems. Climate change, and the corresponding rise in extreme hydrological events, therefore necessitates a significant shift in existing risk management systems in order to build a disaster resilient ASEAN.

The ASEAN Community has recognized the need to tackle existing capacity gaps to address new challenges posed by the rapid rise of extreme disaster events in the region. The ASEAN Agreement on Disaster Management and Emergency Response (AADMER) provides guidance on addressing disasters through enhanced cooperation and regional capacity improvement. Article 5.1 of AADMER asks the parties to take appropriate measures to identify disaster risks in their respective territories. It covers natural and human-induced hazards, risk assessment, vulnerability monitoring and disaster management capacity. The AADMER Work Program 2016-2020 further calls for, as one out of eight priority actions, enhancing risk assessment and improving risk awareness in the ASEAN Community by strengthening capacity in risk and vulnerability assessment, improving the availability of data and information on regional risk and vulnerability, and enhancing risk data utilization and information sharing mechanisms.

In the spirit of AADMER and its work programs, the Japan International Cooperation Agency (JICA) project "Strengthening Institutional and Policy Framework on Disaster Risk Reduction (DRR) and

Climate Change Adaptation (CCA) Integration" Concept Note (CN) 20 (hereinafter, CN20 project) identified a need for practical flood and landslide risk assessment guidelines that incorporate climate change impacts on a river basin scale. The CN20 Project is among 21 flagship and priority DRR and CCA projects identified by the AADMER Work Program Phase 2 (2013-2015). Building on the outcomes of CN20 project, the new ASEAN project "Disaster Risk Reduction by Integrating Climate Change Projection into flood and Landslide Risk Assessment" was initiated through financial support from the Japan ASEAN Integration Fund (JAIF) (hereafter referred as the JAIF DRR-CCA project). The project's core objective is to enhance AMS risk assessment capacity by integrating climate risk. One of its main outputs is development of ASEAN guidelines on flood and landslide risk assessment that assist relevant agencies and sectors to plan and prepare for climate induced risks.

This project developed two separate guidelines for flood and landslide risks. This volume addresses landslide risk assessment.

1.3. Objectives and scope

Extreme hydrological events are on rise across ASEAN and in the future are expected to occur more frequently. The main objective of these guidelines is to assist ASEAN Member States conduct landslide risk assessments and mapping by integrating projected climate change impacts at the river basin level. They are therefore different from other guidelines that reference historical trends and cover regular landslide events. These guidelines are intended to be applied at the river basin level for integrated landslide risk management and planning. They will be useful to:

- Identify landslide risks and associated vulnerabilities resulting from extreme hydrological events and future climate impacts.
- Conduct climate change impact assessments and develop realistic scenarios using landslide susceptibility assessments, spatial tools and mapping methods.
- Conduct vulnerability and damage assessments and identify new vulnerabilities.
- Conduct landslide risk assessments and mapping under different climate change scenarios.
- Map and zone landslide susceptibility and map hazards for landslide prone areas.
- Carry out risk planning through adoption of integrated landslide risk management.
- Conduct community-based landslide risk management and planning.

1.4. Guidelines structure

These guidelines are divided into three parts (**Figure 1.1**): preparation, assessment and planning. They provide a holistic overview of landslide risk assessment to assist decision-making and integrated landslide management implementation.

Figure 1.1 Three main parts of the guideline

Preparatory steps for a landslide risk assessment are indispensable due to the large number of variables involved in the process. These variables must be identified and organized before the assessment. Part one introduces this process and begins with identification of major factors responsible for heightened impacts from hydro-meteorological hazards and a review for understanding key landslide characteristics. As there is a lack of readily available data for landslide risk assessment, this part helps users to understand necessary data (hydromet, geo-spatial and damage), identify data, agencies and stakeholders (including their capacities and coordination), and organize those agencies and stakeholders for landslide risk assessment strategy development. These guidelines will also inform users on how to incorporate climate change into the assessment, as fewer references for it are available. These preparatory steps are fundamental for identifying capacity gaps and choosing appropriate means to obtain missing information, for example through a primary survey or installation of infrastructure for monitoring. These guidelines will help AMS improve data monitoring, storage and processing, and improve information sharing among the agencies that are critical for landslide risk assessments.

Part two of these guidelines covers landslide risk assessment and mapping methods and strategies. It is divided into four sections. The first section describes the climate change impact assessment and scenario development process. The intent is not only for users to understand climate change science basics and recent advances, but also climate predictions for realistic scenario development. The second section covers landslide susceptibility mapping and zonation for observed hydrological conditions, as well as river basin level climate scenarios. The third section focuses on vulnerability assessment, element-at-risk identification and qualitative and quantitative indicators. The fourth and final section illustrates the risk assessment and mapping process through integration of climate assessment, susceptibility analysis and vulnerability assessment results.

Part three of these guidelines covers integrated framework planning. It guides users through risk assessment and mapping for planning and decision-making. It is divided into three sections. The first covers basin-wide planning that incorporates potential structural and non-structural measures. This section guides relevant agencies on necessary river basin level interventions. These intervention measures could include structural development such as drainage, slope protection, vegetation management, hydromet station placement, institutional reform, etc. The second section addresses local level planning, with a focus on preparedness and response. This step is critical due to the localized nature of most hazards. The third and final section provides recommendations on line agency and sector roles and responsibilities for local and river-basin landslide risk management and planning in the short, medium and long-term.

1.5. Guidelines development and target users

The development of these guidelines is a collaborative effort that makes up an integral part of the JAIF DRR-CCA project design. The process adopts both top-down and bottom-up approaches in order to ensure its applicability and relevance across AMS. It has been co-developed with the relevant national and local AMS agencies and is under the direct supervision of the project steering committee headed by the co-chairs of the ASEAN Committee on Disaster Management (ACDM) Working Group on Prevention and Mitigation. River basin pilot (RBP) sites in Myanmar and Lao PDR were used in the project design to demonstrate the landslide risk assessment process. Phoukhoun River Basin in Lao PDR and Taunggyi River Basin in Myanmar were chosen as the RBPs. These sites were selected after consultation with disaster management agencies and relevant stakeholders – a process that also led to formation of the National Project Management Committee. The assessment processes at the RBPs are guided by past and recent landslide incidents and existing capacity gaps, such as lack of data and human resources, institutional setup, local context, etc. Each RBP is composed of a dedicated team nominated by the National Project Committee (**Figure 1.2**).

Photo: Risk and vulnerability assessment - household survey in Phoukhoun, ASEAN DRR-CCA

Figure 1.2 JAIF DRR CCA Project River Basin Pilot (RBP) structure

The RBP team at each site was tasked with the risk assessment process, risk mapping and landslide DRR plan development. The technical team was made up of experts from relevant agencies in AMS, local agencies and other stakeholders, as well as members from the Institute for Global Environmental Strategies (IGES), CTII International Co. Ltd., and the Asian Disaster Preparedness Center (ADPC). The methodology used an adaptive risk assessment approach and was guided by local conditions, taking into account available resources and resource constraints. Open source geospatial tools such as QGIS were used to ensure adoption, as well as process sustainability after the end of the project. An RBP team consisting of members from key line agencies was established at each pilot site, based on host country and project co-chair recommendations. The RBP team gathered necessary data, coordinated with agencies at pilot sites, and assigned dedicated staff to the risk assessment process. RBP team members took the lead in implementing each field survey, while the project team (IGES, CTII, ADPC) provided necessary facilitation and technical support. The field survey concluded with seminars to review progress, findings, and lessons learned for future strategy building. These guidelines' development was based on RBP site exercise experience and outcomes. Experts from the relevant AMS line agencies that took part in the risk assessment process shared their experience and suggestions for risk assessment and mapping.

These guidelines' development process was further complemented by carefully designed case study visits to Thailand and Japan to gain first-hand experience on landslide risk management best practices. RBP members, along with other AMS representatives, participated in the visits. This process (**Figure 1.3**) is an integral part of project risk assessment capacity building.

Throughout all project activities this capacity building 'training-of-trainers' style approach of learning-by-doing was focused on two outcomes: 1) Ensuring key knowledge transfer to AMS, and 2) Gathering input and feedback for guidelines development. In addition, the "Regional Workshop for Development of Guidelines Integrating Climate Change Projections into Flood and Landslide Risk Assessment" was organized on 13-15 February 2020 in Vientiane, Lao PDR. The RBP team and relevant agency experts discussed the draft of these guidelines to determine their scope and provide suggestions for revision and value addition. These guidelines also were peer-reviewed by AMS agencies and experts and project co-chairs to gather further suggestions for improvement.

Relevant AMS disaster management agencies can use these guidelines to either conduct risk assessments, or as a reference to design or oversee landslide risk management projects outsourced to contractors or consultants. These guidelines can also serve as a handy reference for practitioners, private sector companies and development agencies tasked with disaster risk management. ASEAN agency staff working on river basin planning or incorporating climate risks into disaster management plans can also use these guidelines to support decision-making. Their use is additionally expected to improve inter-agency coordination on data organization, management, and sharing for risk assessment – a common need identified during project implementation. To address data, capacity (technical and human resources) and finance gaps, these guidelines will assist implementing agencies in choosing the best risk assessment approaches for a given situation and then progressively fill identified capacity gaps. When including RBP landslide risk assessment methods, results and case visit lessons, these guidelines can be used to replicate risk assessment in other AMS river basins.

Figure 1.3 Guidelines development information sources

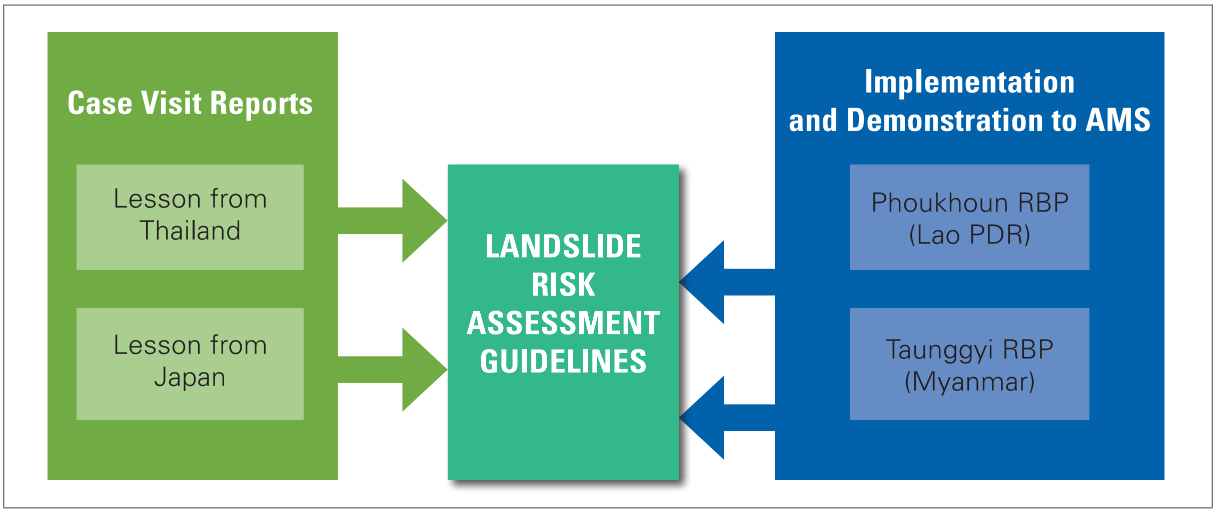
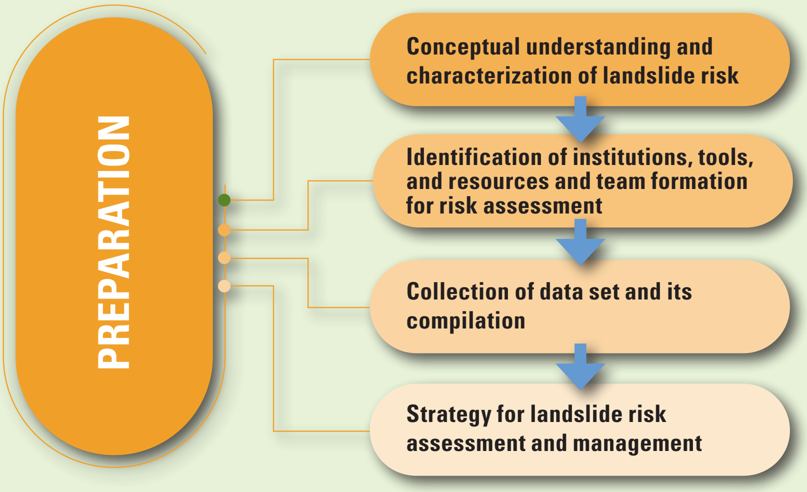


Photo: *Community-based disaster risk management exercise in Taunggyi, ASEAN DRR-CCA*

Photo: Community-based disaster risk management exercise in Phoukhoun, ASEAN DRR-CCA

2 PREPARATION OF LANDSLIDE RISK ASSESSMENT



PART I: PREPARATION

These guidelines divide landslide risk assessment preparation into four steps that can be modified according to user needs. These steps promote a comprehensive understanding of the landslide risk profile in a given situation, including climate change factors, and then provide guidance for adopting the most practical risk assessment approach given constraints such as the dataset, information and tool availability, financial resources, and institutional, human, and technical capacity.

2.1. Understanding and characterizing landslide risk in a changing climate

The first assessment preparatory step consists of a conceptual understanding of landslide risk and the role of climate change in shifting the risk profile dynamics, as well as getting acquainted with essential assessment strategies. After learning the basic landslide risk assessment concept, the next step in the process is characterizing landslides based on the changing profile of hazards triggered by extreme hydrological events, biophysical (topographic, soil, geological, land use and land cover) factors, and developmental and environmental changes.

Disaster risk is a compound concept that lies at the intersection of hazards, exposure and exposed elements vulnerability, as shown in **Figure 2.1**. The United Nations Office for Disaster Risk Reduction (UNDRR) defines disaster risk as the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, and capacity.

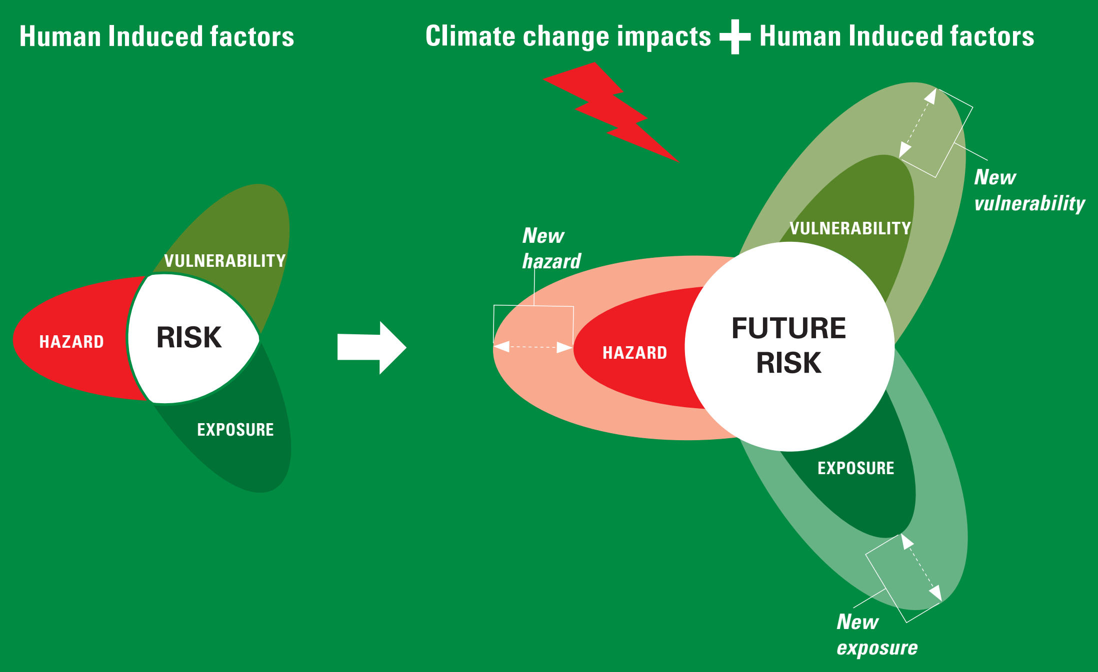


Figure 2.1 Disaster risk as an intersection of hazard, exposure and vulnerability without (left) and with climate change (right). Climate change impacts are expected to increase disaster risk due to increases in new hazards, exposure and vulnerabilities.

The UNDRR definition recognizes that disaster risk results from a series of independent components associated with hazard type (which vary in frequency, intensity, duration, and onset rapidity), and exposed element (assets, population, environmental features) vulnerability originating from various physical/ structural, social, economic, and environmental factors. The main factors intensifying future disaster risk include increases in exposure due population and economic growth and vulnerability resulting from the above mentioned socio-economic and physical factors.

Landslide triggers are often associated with sudden onset events such as earthquakes, storms, or tropical cyclones. In the majority of cases, however, disaster risk accumulates slowly and continuously over time. The sudden onset nature of landslides therefore makes measuring accumulated risk difficult. There is a general perception that landslides are random natural phenomena. This perception must be changed through better understanding of accumulated risks. The majority of government and specialized agency-initiated actions on landslides are insufficient as they are conceptualized and planned around disaster response and relief. A re-thinking of actions that includes hybrid solutions that combine engineering risk mitigation intervention, land-use planning and vulnerable community resettlement is needed.

Climate and global environmental changes caused by anthropogenic activity are altering hazards by changing their susceptibility, coverage, frequency and severity. The 2012 IPCC Special Report on Extreme Events warns that many hazards will be exacerbated by climate change. In particular, climate change is likely to affect hydro-meteorological hazard patterns and their frequency, intensity and extent and spatial distribution.

While historical landslide event lessons serve as valuable inputs for risk assessment, they are not necessarily adequate when considering climate change as a factor. Expanding current risk into future risk poses additional challenges for identifying new exposure elements and vulnerabilities, as well as for expanding the hazard element scale (**Figure 2.1**). Changing landslide profiles should be examined and characterized before starting a landslide risk assessment. An assessment should start with inspecting the landslide hazard area during the baseline survey. **Figure 2.2** shows a typical landslide located along a road in the Phoukhoun RBP study area in Lao PDR. The inspection would include identification of key factors contributing to the landslide.

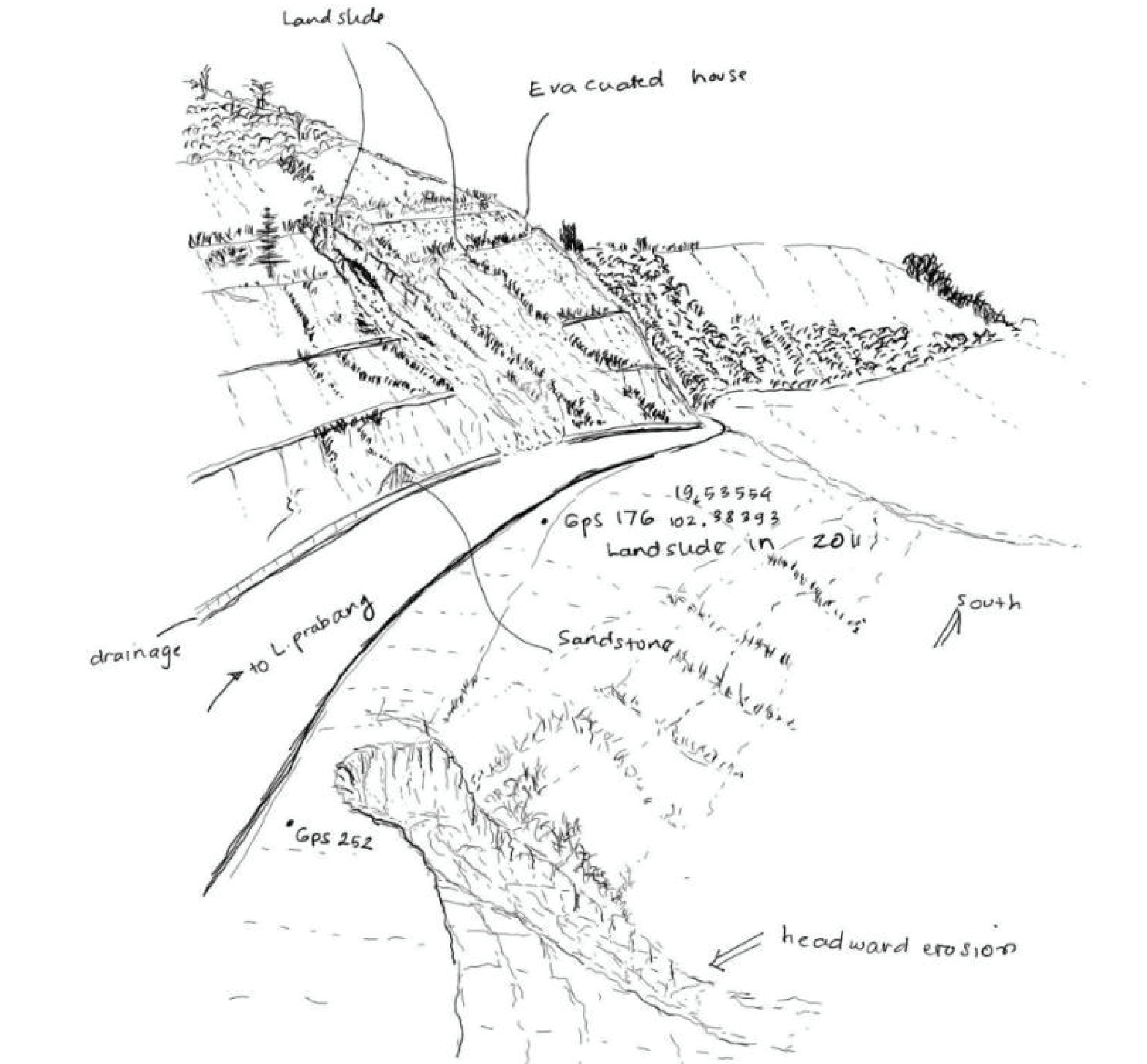


Photo: Project baseline survey filed notes by Dr Rendy Dwi Kartiko

Figure 2.2 Typical landslide along a road in the Phoukhoun, Lao PDR study area (Source: Project baseline survey field notes by Dr Rendy Dwi Kartiko)

Several natural and human induced factors contributed to the most prevalent landslide hazard risks in the Phoukhoun area, with all landslides triggered by heavy rainfall. Heavy rainfall is becoming the leading cause of compounding risk. In Myanmar, extensive slides in Hakha were caused by Cyclone Koman in July, 2015. Heavy rainfall over a short time period, including 180 mm on July 27, passed the area threshold value, leading to slide triggers. In addition to Hakha, landslides in Myanmar's Tanintharyi, Bago Yoma, Maechi and Mt. Popa areas in recent years were also caused mainly by torrential rainfall. The recent landslide increases in the Taunggyi RBP site in Myanmar can be attributed to additional road construction and development activities, particularly on slopes and in hilly areas. High and untimely rainfall events in recent years have coincided with seasonal vegetation cycles. Soil erosion due to economic activities and land cover loss has also contributed to recent landslides. At the Phoukhoun RBP site in Lao PDR, recent landslides can be attributed to high precipitation events (such as those that happened during 2018), the mountainous relief, and alteration of geological formations due to human activity.

To characterize a landslide, its causes and trigger mechanisms, as shown in **Table 1.1**, must be understood. This includes review of past landslides (location, types, damages, response, etc.), land-use changes and socio-economic profiles, as well as a topography, slope, hydrology, temperature and soil types. Knowledge of landslide triggers and causes is the basis for choosing a methodological framework and developing an appropriate strategy.

Table 1.1 Landslide causes and trigger mechanisms

Physical causes and triggers	Natural Causes		Human Causes
	Geological	Morphological	
Heavy rainfall	Weak materials, such as volcanic slope or unconsolidated marine sediments	Tectonic or volcanic uplift	Excavation of the road or its toe
Rapid snowmelt	Susceptible materials	Glacial reborn	Use of unstable earth fills for construction
Heavy prolonged precipitation	Weathered materials	Glacial meltwater outburst	Loading of slope or its crest, such as placing earth fill at the top of a slope
Rapid drawdown (of floods or tides) or filling materials	Sheared materials	Fluvial erosion of slope toe	Drawdown and filling (of reservoirs)
Earthquake	Jointed or fissured materials	Wave erosion of slope toe	Deforestation
Volcanic eruption	Adversely oriented mass discontinuity (bedding, schistosity, etc.)	Glacial erosion of slope toe	Irrigation and or lawn watering
Thawing	Adversely oriented structural discontinuity (fault, unconformity, contact, etc.)	Lateral margin erosion	Mining/mine waste containment
Freeze-and thaw weathering	Contrast in permeability	Subterranean erosion (solution, piping)	Artificial vibration such as pile driving, explosion and/or other strong ground vibrations
Shrink and swell weathering	Contrast in stiffness (stiff, dense material over plastic materials)	Deposition loading slope or its crest	Water leakage from utilities such as water or sewer lines
Flooding		Vegetation removal (by forest fires or drought)	Diversion (planned or unplanned) of a river current or longshore current by construction piers, dykes, weirs, etc..

Source: The Landslide Hand Book – A Guide to Understanding Landslides, USGS

2.2. Institutions, tools, resources and landslide risk assessment team formation

To address natural, social, and cultural factors, landslide risk assessment requires a diversity of expertise and stakeholders. An understanding of institutional arrangements at different levels is necessary. This includes their coordination mechanisms, as well as monitoring systems, tools, human resources and funding capacity. As key institutions and agencies might be the only sources of critical information, their current standing and circumstances can determine risk assessment actions. These institutions and agencies hold decision-making authority and engage relevant staff and allocate resources. They are also responsible for coordination and facilitating the risk assessment process by providing data, resources, and technical and support staff. The RBP team in this project was formed to engage key institutions and ensure relevant staff participation in the entirety of the risk assessment and mapping process. In addition to engaging relevant agencies, the RBP team also helped identify areas where coordination was lacking and new mechanisms should be established. Knowledge on implementing agency division of roles and responsibilities will guide and define key expert and specialist requirements for risk assessment support, as well as help evaluate expert and specialist performance during implementation. This holds true even if the assessment is outsourced to consultants or other firms.

Parallel to institutional arrangement knowledge, it is vital to understand existing capacity and gaps in the collection and sharing of information such as hydro-meteorological, geospatial and biophysical (geology, soil, land use, land cover, topography, etc.), available structural and non-structural measures, and exposure and damage data. In addition to robust data and information, risk assessment and mapping will require tools such as hydrological models, GIS systems, etc. The RBP used open source QGIS risk assessment and mapping software for the demonstration. Data, information, tools and resources are often spread across line agencies, and are stored and retained by more than one organization at different hierarchal levels. Failure to understand and streamline them before starting the analysis will waste time, cost, and effort, and potentially invite unwanted frictions among agencies. These inefficiencies eventually lead to poor landslide risk management. This preparatory work should serve as a pre-requisite for landslide risk assessment to stress the need for an efficient data sharing mechanism, applied both vertically and horizontally, among agencies.

After gaining institution and agency knowledge and mapping their capacities, a team with clear demarcation of roles and responsibilities must be formed. Team make-up should include a healthy combination of technical experts, representatives from relevant agencies (such as water resources, geology, meteorology, agriculture and forestry, plus local authorities responsible for DRR, etc.), and local stakeholders and at-risk populations, including vulnerable groups such as the elderly, women, children and the differently abled. Collaboration among professionals that have proven experience in landslides and landslide risk assessment is encouraged. This might include national, provincial (sub-national) and local authorities (decision makers) with academic and research institutions. This group may jointly agree on various risk modeling approaches, depending on need. These approaches can include, for example, using probabilistic means for landslide risk delineation at the regional level for physical planning purposes, whereas, for local level risk reduction actions to promote mitigation, deterministic means are more suitable.

Team members should be flexible, depending on the nature of activities and responsibility, and be ready to work in groups or individually, depending on need at the different assessment stages. For example, in most cases technical members will lead the overall assessment, while stakeholder or agency involvement could be limited to specific processes. The intent is to ensure inclusiveness and meaningful participation so that all necessary factors and criteria are incorporated in the process. The assessment team should be need-based and agile, with a clear demarcation of roles and responsibilities at each assessment stage. This project's stakeholder inclusiveness serves as an example of team formation for mapping, planning and assessment.

Photo: Phoukhoun, ASEAN DRR-CCA

2.3. Dataset collection and compilation

Data and information are fundamental for a reliable landslide risk assessment, as the assessment process is data intensive. Data gathering requires a great deal of effort. Alternative approaches to treat gaps must be found if data and information is unavailable. This includes preparing data for landslide inventory and attributes, as well as for precipitation, socio-economic data, etc. These alternative approaches suggest methods for baseline data verification and record keeping, and are additionally used for maintenance and streamlining data sharing.

A landslide risk assessment requires data and information on hazards, exposure, and vulnerability (**Figure 2.1**). Baseline data required for the hazard and exposure assessment, such as that pertaining to administrative, hydro-meteorological, historical disaster events, socio-economic and infrastructure, etc. can be collected from different sources, while vulnerability related data and information for this study was collected through the household survey. A more detailed discussion on data collection can be found in following sub-sections.

Geo-spatial data mainly covers topography (elevation, slope and aspect), stream network, geology and soil types, land use and land-cover maps, road network, etc. (**Figure 2.3**).

Elevation
An elevation map can be generated from a digital elevation model (DEM) derived from open sources such as SRTM (Shuttle Radar Topographic Mission) satellite imagery with a 30-meter pixel size. The DEM could be grouped into several classes to distinguish the changes in topography. The DEM data obtained from SRTM imagery is usually in longitude/latitude coordinates, and must be projected to an appropriate system such as the Universal Transverse Mercator (UTM) projection system. For the DEM to cover the study areas, the clipping process using watershed boundaries (as study areas) should be completed.

Slope gradient
Slope is a measure of steepness using a degree of inclination relative to the horizontal plane. It is typically expressed as a percentage, an angle, or a ratio. Slope gradient can be generated from the DEM of a 30-meter pixel SRTM. Before generating a slope gradient, the map projection needs to be translated into a specific geographical area UTM (meter units), for example UTM zone 47N (for Myanmar).

Slope aspect
Slope aspect is also known as slope orientation or slope azimuth. It represents the direction of a slope. Aspect can be classified according to the slope angle with a descriptive direction. An output aspect raster (horizontal lines composed of individual pixels) will typically result in several slope direction classes. Aspect is measured clockwise starting north at 0° and returning back to 360° north.

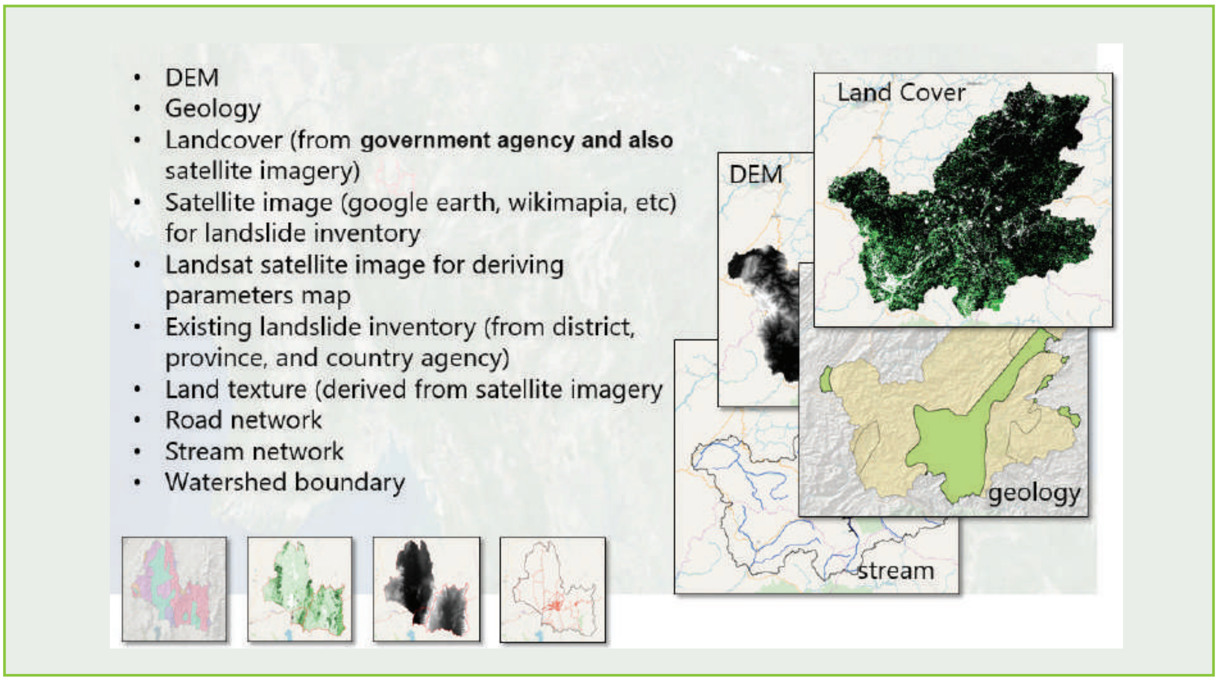


Figure 2.3 Landslide susceptibility analysis geo-spatial data sample


Photo: Taunggyi, ASEAN DRR-CCA

Distance from road
Proximity to roads is also considered a potentially important factor because road construction usually includes land or material excavation in some slope areas and the addition of land or materials to the slope in other areas. This might result in slope line changes, artificial slope creation or road cuts that might be affected by landslide activities (Che et al., 2011).

Distance from river
Proximity to a river may adversely affect slope stability due to slope toe undercutting, or saturation in the lower part of the slope, resulting in a water level increase.

Land use and land cover
A land use and land cover map can be derived from processing satellite imagery, such as Landsat, or can be obtained from existing maps kept by relevant agencies. In this study, the land use and land cover map was derived from the regional land cover monitoring system developed by the SERVIR-Mekong program. SERVIR has produced a series of annual land cover maps with multi-purpose typologies using Landsat images from 2000-2017 at a 30-meter resolution.

Hydro-meteorological datasets
Hydro-meteorological data consists of a precipitation (mainly rainfall) time-series. Additionally, temperature and humidity can often be collected from ground observation stations, as well as remote sensing sources. In this study, rainfall datasets that were used for the RBPs were derived from historical climate data and future climate projections.

(i) Historical meteorological data

This project used historical precipitation information that included globally and regionally available historical meteorological datasets such as CHIRPS precipitation data from 1981 to date from the Climate Hazard Group (CHG), with 5x5km^2. Additional datasets used include the APHRODITE project precipitation data from RIHN/MRI/JMA from 1951 to 2007, with 25x25km^2 resolution, as well as locally collected in-situ data from 1981 to 2016. In-situ data availability varied from station to station.

(*ii) Climate projection data*

The NASA Earth Exchange (NEX) models (CMIP5 models) that include future climate change scenarios from 21 Global Circulation Models (GMCs) under two emission scenarios (RCP 4.5 and 8.5) with 25x25km^2 resolution provide a reliable database and were used as the main future climate reference point for the project.

The precipitation data projections used for the landslide susceptibility analysis were derived from the NASA Earth Exchange (NEX) models covering the Phoukhoun (Lao PDR) and Taunggyi (Myanmar) study areas for the following time horizons: 2030s, 2050s and 2080s (15 days before and 10 days after peak rainfall during the monsoon season).

Landslide inventory
A landslide inventory is a detailed register of the distribution and characteristics of past landslides. Historical disaster data (location, type, damage scale, response, etc.) and the subsequent landslide

Photo: Risk and vulnerability assessment-household survey in Taunggyi, ASEAN DRR-CCA

inventory preparation are important for generating the landslide hazard/susceptibility map. This map exercise and the subsequent risk assessment process are based on statistical methods. A landslide inventory can be built using past records and high-resolution satellite imagery, such as Google Earth or Sentinel.

Currently there are no comprehensive landslide inventory databases covering the Lao PDR and Myanmar study areas. In the absence of these detailed landslide inventories, an inventory covering the study areas was created using free access satellite images, such as those from Google Earth. This additional landslide inventory data helps generate better landslide susceptibility prediction accuracy.

Socio-economic data

Socio-economic data includes demography, assets (houses, property, and businesses), infrastructure (roads, structural measures for landslide prevention), and critical services (education, health, markets, water supply) that are exposed to a landslide. Socio-economic data is often the key input for a vulnerability analysis, as well as for risk assessment strategy development.

There are typically two types of socio-economic data. First is the observed raw data that has to be preprocessed before use. Second is processed data that can be used after basic checks for accuracy and missing data. As processed data is a derivative of raw data, its complexity normally assures its accuracy.

Required assessment data can be sourced from past assessments, research or secondary sources from line agencies at different levels. When local data is not available, it could be sourced from global data such as DEM or Google Earth satellite images. Certain datasets, however, such as those pertaining to vulnerability and damage, require a primary field survey.

Before utilizing the collected data, each data type should be checked for reliability based on correctness, consistency, and completeness. The reliability check and needed corrections are critical to ensure accuracy in the risk assessment and mapping process.

Data often comes from a wide range of sources and is in different formats. The data should therefore be preprocessed and compiled before beginning the assessment process. For GIS spatial data processing, parameter data preparation must meet certain conditions. The parameter data must have the same projected coordinate system and same scope, resolution and number of pixels, which can be fulfilled when using the same coverage references, for example watershed boundaries. Parameter data must be transferable in GIS, ideally in a raster format, as the analysis is done in a GIS environment using freely available QGIS software (or commercially available ArcGIS) and the spatial analyst module.

2.4. Landslide risk assessment strategy development

After reviewing the problem in question, the complexity involved, level of current and future risk, including risk caused by climate change, as well as data and available information, resources, tools and institutional capacity, the final preparatory step is to develop a landslide risk assessment strategy. The strategy should have a clear purpose and scope and be realistic.

Landslide risk assessment is a prerequisite for creating the most appropriate risk management strategy. The assessment will help understand the setting, demarcate landslide areas, determine hazard parameters and estimate probable landslide risk. For example, the risk assessment could be based on high resolution rainfall data to estimate rainfall thresholds that trigger landslides. For all ASEAN country areas that are landslide prone, hazard and risk evaluation is a common objective for demarcating zones considered safer for urban and land use planning, as well as for protection measure optimization. Landslide susceptibility mapping is one of the steps that can be taken to identify landslide prone areas and acquire data for selecting and adapting various risk management options. Though present landslide risk levels may not be very high, they can grow in the near future if landslide potential is ignored and authorities do not take proper precautionary measures to mitigate potential risk. Therefore, the changing climate, along with development patterns and environmental degradation, shows that disaster risk is dynamic and involves complex interaction. This demands regular landslide assessment and re-assessment.

These considerations should be taken into account when devising the landslide risk assessment and management strategy. Landslide risk assessment should include basic information and risk knowledge for various risk management purposes, including:

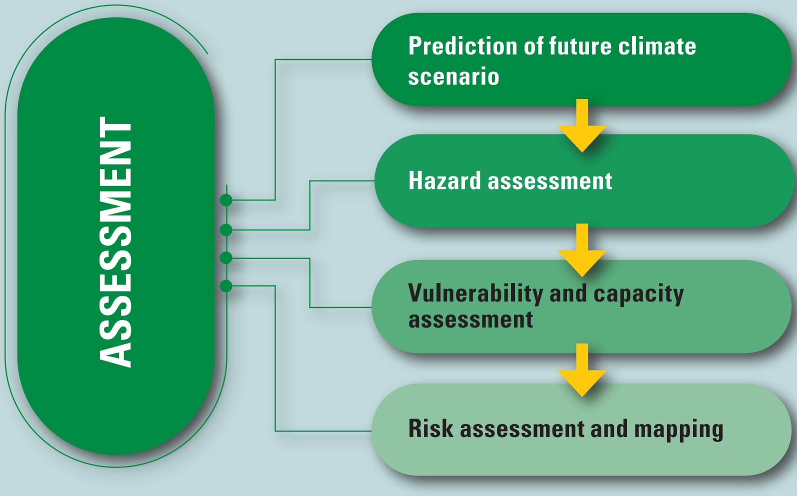
- General resilience building through identification of geo-political areas affected by landslide hazards.
- Risk management schemes designed through analysis of potential disaster scenarios on areas that can be affected such as individual economy sectors, population, infrastructure, etc.
- Potential disaster event physical damage and economic loss estimation.
- Quantitative assessment for defining financial needs and priorities for economic recovery and reconstruction in case of a disaster event.
- Government capacity analysis to meet its post-disaster needs and identify needed external assistance, for example, international cooperation requirements for immediate and long-term recovery.
- Determination of disaster impact on economic development and macro-level planning decisions.
- A baseline definition for monitoring the progress of risk reduction measures.
- Determination of changes or introduction of modifications to public policies to lessen disaster impact and facilitate economic recovery after disaster events.
- Mapping specific agency needs and sharing risk knowledge with respective agencies.

Further details on data preparation can be found in the Taunggyi (Myanmar) and Phoukhoun (Lao PDR) RBP landslide risk assessment technical reports.

Photo: Mapping Exercise - Phoukhoun, ASEAN DRR-CCA

Photo: Taunggyi - RBP Site, ASEAN DRR-CCA

3 FUTURE CLIMATE CHANGE PROJECTION AND SCENARIO DEVELOPMENT



PART II: ASSESSMENT

A Landslide risk assessment is divided into four sub-sections: 1) Future climate scenario prediction, 2) Hazard assessment, 3) Vulnerability and capacity assessment, and 4) Risk assessment and mapping. Data and resource availability and assessment purpose will need to be weighed against required effort and available capacity to ensure the assessment is appropriate and achievable.

The objective of an impact analysis is to assess the effect of climate change on social, ecological, and physical systems using analysis of current trends in applicable climate parameters, as well as to assess the impacts of these climatic trends on social, ecological, and physical systems and develop climate scenarios for an appropriate time frame at appropriate temporal and spatial scales (ADB, 2017). This section introduces recent advances in climate scenario development and explains scenario application for landslide risk assessment and mapping. One of the critical challenges for scenario development is to downscale global and regional scale projections to a river basin scale, as this process is fraught with high uncertainty. As a result, downscaled projection use at the local or river basin scale is not straightforward. A cautious approach must be adopted and results should be contrasted according to the local context. A good understanding of data, climate simulation mechanisms and projections and uncertainties is essential to develop realistic scenarios and properly assess risks in the local context. The process should be designed so that decision makers will be able to understand, interpret and use the results from climate simulations and projections to develop realistic scenarios for planning, mitigation measure design, and implementation.

The changing climate may lead to changes in the frequency, intensity, spatial extent, duration, and timing of weather, and can result in unprecedented extremes (Seneviratne et al., 2012). Weather or climate events that may not be extreme in a strict statistical sense can nevertheless cause extreme conditions or impacts, either by crossing a social, ecological, or physical system critical threshold, or by occurring simultaneously with other events. Some climate extremes may not be the result of one event but an accumulation of multiple single events (Seneviratne et al., 2012). It is therefore important to attribute a rise in extreme events to normal and recurring events, or those that are a result of a changing weather profile. There are three types of challenges. The first is to understand the contribution of global warming relative to triggering extreme hydrological events on a given scale, intensity and frequency. The second is to predict by how much global warming induced climate change will escalate future extreme hydrological events. The third, and most important, challenge is how to correctly predict abnormal changes in a hydrological event at a given spatial scale, and use that prognosis to minimize uncertainty in decision making.

3.1. Predicting future climate scenarios with datasets

Climate projections are widely used datasets to understand climate extremes and extreme occurrence probability in the future. Four sources are available (Seneviratne et al., 2012; Christensen et al., 2007; Knutti et al., 2010) to inform the construction, assessment, and communication of climate change projections, including regional projections for extremes:

- Global Climate Models (GCMs)
- GCM simulation downscaling
- Physical understanding of the processes governing regional responses
- Recent historical climate change

The IPCC AR4 used GCMs as the main source of regional information on the range of possible future climates, including extremes (Christensen et al., 2007). The AR4 concluded that present-day extreme event climate statistics, especially those on temperature, could be well simulated by current GCMs at the global scale, although this does not hold true for precipitation extremes (Randall et al., 2007). GCMs can be useful for investigating smaller-scale features, including changes in extreme weather events, with improvement in their spatial resolution and complexity.

Global and regional historical meteorological datasets are available from several sources. Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) precipitation data from 1981 to date with 5x5 km^2 resolution is available from the Climate Hazard Group (CHG). The Asian Precipitation Highly-Resolved Observational Data Integration Towards Evaluation (APHRODITE) project precipitation data from the Research Institute for Humanity and Nature (RIHN)/ the Meteorological Research Institute of the Japan Meteorological Agency MRI/JMA) from 1951 to 2007 with 25x25km^2 resolution is also available. For temperature, fifth generation ECMWF atmospheric re-analysis of the global climate (ERA5) temperature data from 1950 to the present is available from the Copernicus Climate Data Store. Additional data needed for result verification includes in-situ meteorological data (rain gauge, temperature data) over a longer period.

3.2. Developing climate change projections

All climate change studies (including landslide risk assessments) require future projection of climate variables such as rainfall, temperature, wind, sea level rise, etc. Rainfall change is the key variable used in a landslide risk assessment to examine future extreme rainfall that could trigger larger scale landslide hazards.

It is important to note that climate projections are not forecasts or predictions of the future, but they instead estimate likely future climates due to future human induced socioeconomic and technological development activity. Projections are usually sourced from global (GCMs) or regional (RCMs) climate models. Before using climate projections for landslide or other impact models, results should be processed and downscaled to represent the assessment area climate. **Figure 3.1** shows the climate change projection development process based on the methods used in this project. The RBP landslide risk technical reports can provide the detailed process and outcomes.

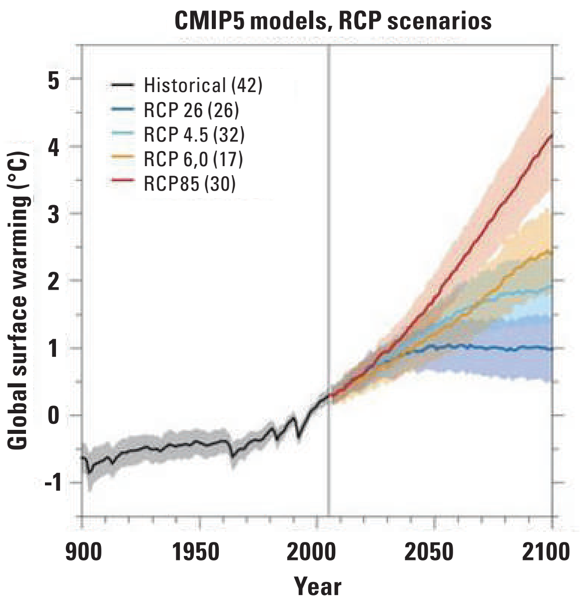
The Intergovernmental Panel on Climate Change (IPCC) Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA) also provides general guidelines on data and scenario use for impact and adaptation assessments.

http://www.ipcc-data.org/guidelines/#ClimScenSD

Figure 3.1 Proposed climate projection process for landslide risk assessment at a river basin scale

3.3. Selecting suitable climate scenarios

A climate scenario is a predicative representation of future climate that has been constructed to investigate the potential impacts of anthropogenic climate change (IPCC, 2018). Here it refers to representative concentration pathways (RCPs) that provide atmospheric concentration projections of greenhouse gases. Climate scenarios serve as the main input to General Circulation Models/ Global Climate Models (GCMs). RCPs are the latest generation of scenarios that inform climate models. They illustrate different climate futures, all of which are considered to depend on future greenhouse gas (GHG) emission volume. There are four pathways: RCP8.5 (high emissions), RCP6.0 (intermediate emissions), RCP4.5 (intermediate emissions) and RCP2.6 (low emissions). The goal of a scenario is not to predict the future, but rather to better understand uncertainties and possible alternatives to probe the feasibility of decisions or options under a wide range of possible futures. More information: https://www.ipcc-data.org/guidelines/pages/ glossary/glossary_r.html



3.4. Global Climate Model projection

Global Climate Models (GCMs) are mathematical representations of the climate system that run on high-performance computers. GCMs are coupled with ocean, atmosphere, sea ice and land surface systems that use emission scenarios (RCPs) for projecting the future climate. The Coupled Model Inter-comparison Project Phase 5 (CMIP5) is the latest dataset group with simulation from the new generation of GCMs (Rupp et al., 2013). The 40 plus GCMs in the CMIP5 archive have different spatial resolution and are developed by various meteorological organizations and agencies. In the fifth assessment report of the IPCC (AR5), climate simulations have been completed for the 21st century according to RCPs based on four greenhouse gas concentration trajectories (Demirel and Moradkhani, 2016). More information: https://www.ipcc-data.org/guidelines/pages/gcm_guide.html

GCMs may have significant biases that vary between models, climate variables and regions. To address this variability for an impact assessment, a mix of GCM model results is recommended. At least three GCMs that fall into low, medium and high scenario projection should be used. For assessments that focus on extreme events, GCMs that represent the highest and lowest extremes should be selected to fully capture climate change variability.

Photo: Household survey - Taunggyi, ASEAN DRR-CCA

How to select suitable GCMs for a study

All GCMs in the CMIP5 are not applicable for all regions of the globe. GCMs are required to be selected from those available under CMIP5 based on the region or area of interest. The GCM could be initiated based on published reports and journal papers, as well as a thorough historical climatological analysis.

- Literature review: A comprehensive review of published reports and peer-reviewed journals can help to identify a GCM suitable for the region or area of interest. For the RBPs in Myanmar and Lao PDR that inform these guidelines, the report "Evaluating the Performance of the Latest Climate Models Over Southeast Asia" published by The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australia for the Asian Development Bank (ADB) was used to identify and select suitable models for the Southeast Asia region (**Table 2.1**) (Hernaman et al., 2017). A subset of CMIP5 models in the report was identified based on metrics that left out the least realistic models but included models that captured the maximum possible range of change with satisfactory performance across all the metrics [67].
- Climatological analysis: A historical climatological analysis can be completed for the area or region using key weather and climate processes such as monsoon patterns, the Madden-Julian Oscillation (MJO), the El Nino Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), tropical cyclones, sea surface temperature (SST) and surface rainfall and temperature patterns and trends. As with the literature review, this analysis will help identify a subset of CMIP5 models based on metrics that left out the least realistic models but included models that capture the maximum possible range of change with satisfactory performance across all the metrics.

Photo: Landslide Case Visit in Uttaradit, ASEAN DRR-CCA

GCM data can be accessed from:
IPCC Data Distribution Centre: https://www.ipcc-data.org/index.html
The Earth System Grid - Center for Enabling Technologies (ESG-CET) http://esgf-node.llnl.gov/

The following 11 GCMs are considered to be satisfactory for Asian and Southeast Asian Countries.
(Hernaman V, Grose M and Clarke JM (2017) Evaluating the performance of the latest climate models over Southeast Asia. (CSIRO, Australia)

bcc-csm1-1, BNU-ESM, CanESM2, CMCC-CM, CSIRO-Mk3-6-0, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, IPSL-CM5A-MR, MPI-ESM-LR, MPI-ESM-MR

Some countries have selected GCMs suitable for their local context.

Vietnam: CNRM-CM5, CCSM4, NorESM1-M, ACCESS1.0, MPI-ESM-LR, GFDL-CM3
(Technical report on High-Resolution Climate Projections for Vietnam published by IMHEN (2014))

Indonesia: MIROC5 *(BMKG-Indonesia)*

Thailand: IPSL-CM5A-MR, GFDL-CM3 and MRI-CGCM3 *(Thailand-Third National Communication)*

Table 2.1 Selected Global Climate Models for the Southeast Asia Region

GCM	Modeling Group
ACCESS1.0	CSIRO and BoM, Australia
bcc-csm1-1	Beijing Climate Center, China
BNU-ESM	Beijing Normal University, China
CanESM2	Canadian Centre for Climate Modelling and Analysis, Canada
CMCC-CM	The Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy
CNRM-CM5	National Centre for Meteorological Research, France
CCSM4	National Center for Atmospheric Research, USA
CSIRO-Mk3-6-0	CSIRO Atmospheric Research, Australia
GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory, NOAA, USA
IPSL-CM5A-MR	Institut Pierre Simon Laplace, France
MIROC5	Center for Climate System Research, Japan
MPI-ESM-LR, MPI-ESM-MR	Max Planck Institute, Germany
NorESM1-M	Norwegian Climate Center, Norway

3.5. Regional Climate Model projections

Regional climate models (RCMs) (**Table 2.2**) are widely used to produce climate information on a regional scale to support regional climate variability and change studies. While GCM simulations drive RCMs, they have advantages in that they cover a specific geographical area and have better resolution than GCMs. RCMs can also realistically simulate climate parameters as they capture the regional topography and land surface features well. RCMs have their own biases, in particular in relation to the physical parameterization used for describing sub-grid scale climate features. RCM projections therefore also suffer from variability.

The Intergovernmental Panel on Climate Change (IPCC)'s Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA) also provides general guidelines on how to construct and use climate scenarios from RCM outputs and statistical downscaling methods

http://www.ipcc-data.org/guidelines/#ClimScenSD

Table 2.2 Common Regional Climate Models

RCM	Developer
PRECIS	Met Office, UK
RegCM	International Centre for Theoretical Physics (ICTP), Italy
WRF	National Center for Atmospheric Research (NCAR), USA

To address this variability when completing an impact assessment, a mix of RCM model results is recommended. At least three RCMs that fall in the low, medium and high scenario projections should be used. In studies focused on extreme events, the RCMs representing the highest and lowest conditions should be selected for the impact assessment to fully capture climate change variability.

3.6. Downscaling

Climate variable assessments that are simulated by the GCMs are global in scale and are not generally appropriate for assessing climate change impacts at regional and local levels for decision-making processes in sectors such as agriculture, health, transportation, energy and water resources management. Scientists have therefore taken steps to translate the global data from GCMs for use in regional and local impact analyses (**Figure 3.2 Approach of Climate Downscaling**). This process is known as 'downscaling'.

Global

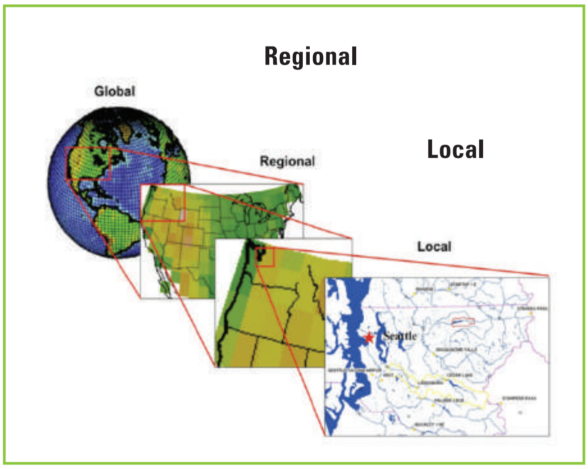


Figure 3.2 Downscaling Approach

There are two general approaches: statistical downscaling and dynamical downscaling. Statistical downscaling uses statistical relationships from GCMs to predict local climate variables [Benestad et al., 2008; Wilby et al., 1998]. Dynamical downscaling uses RCMs to dynamically extrapolate the effects of large-scale climate processes to regional or local scales of interest.

Statistical downscaling was used for the RBPs in these guidelines. A straight bilinear univariate resampling method has been used to convert 25kmx25km resolution precipitation data into a 1kmx1km resolution grid. The APHRODITE data set is used as the reference surface to resample precipitation surface. This resampling process can generate approximate patterns as per the reference data surface and it doesn't disturb the pattern of the original GCM. Downscaling to 1kmx1km was carried out in selected GCMs using the above process. Downscaled 1kmx1km resolution datasets were used for developing future climate projections and hotspot analyses for target areas

3.7. Impact modeling

Climate projections provide a range of possible future climate scenarios. Projection values can thus be used as a guidance for the impact assessment, as well as related planning and decision making. Below is a summary of key actions for impact modeling climate projection data preparation.

RCM driven downscaled data can be accessed from:
CORDEX East Asia: https://cordex.org/domains/region-7-east-asia/

Bias correction and Statistical Downscaling dataset:
NASA Earth Exchange Global Daily Downscaling Projections:
https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp

National Level Approaches:

Indonesia: HadGEM2-ES (RegCM4 RCM Driven) *[Indonesia-Third National Communication]*

Philippines: HadCM3Q (PRECIS RCM Driven)

Thailand: MPI-ESM-MR and EC-Earth (RegCM4 RCM Driven) *[Thailand-Third National Communication]*

Vietnam: CNRM-CM5, CCSM4, NorESM1-M, ACCESS1.0, MPI-ESM-LR, GFDL-CM3, HadCM3Q

(CCAM, RegCM4, PRECIS RCM Driven) *[Technical report on High-Resolution Climate) Projections for Vietnam published by IMHEN (2014))*

- Select an applicable subset of GCMs from those available based on the region or area of interest.
- Use the selected models to capture the full range of potential future climate change. Adoption of a multi-model approach for both GCMs and RCMs is preferable. For probing future extreme conditions, GCMs and RCMs that generate extreme conditions using a stable scientific method are recommended.
- To ensure climate variation and variability are correctly accounted for in climate change projections, use an appropriate length of time, for example 20-30 years, for the baseline period and the same number of years for the future period. Downscaled projections using RCMs or other methods should be combined with relevant GCM information, as the downscaling may not have the same reliability as the GCM projections.
- For comparing projections with different emission scenarios, use the same set of selected models (GCMs and RCMs), for example, comparing outputs for RCP4.5 against outputs for RCP8.5. Similarly, since there is no internal consistency in climate patterns, do not mix the results of different climate variables obtained from different models. For example, do not use a temperature projection from one GCM or RCM and a precipitation projection from another GCM or RCM.
- It is important to address biases in model results. This can be done by converting results to changes with respect to a baseline period, or by using an applicable bias correction approach.
- Emission scenario selection depends on the timeline being used. For near-future predictions, it may not be necessary to use a full range of emission scenarios, as these scenarios may not have significant differences. On the other hand, medium and distant future projections those for adaptation and planning purposes should utilize multiple scenarios.

3.8 Estimating uncertainties and flexible decision making

Uncertainties in climate projection development are inherent as this action involves downscaling of global climatic phenomena to a regional and then local scale (for example, RBP sites). Knowing the factors responsible for uncertainty helps users understand and interpret the results of impact modelling for decision-making.

Two factors should be considered when addressing uncertainties in climate modeling. First is the uncertainty related to the GCM itself, for example, that related to climate system response and natural variability. Second is uncertainty in future emissions and concentration of greenhouse gases (GHGs). GCM uncertainty can be adjusted and minimized using projections from a range of GCMs with different initial conditions. The uncertainty in future GHG emissions concentration can be addressed using a number of GCMS with a range of emission scenarios.

The selection of best available approaches or strategies for climate modelling and projections does not indicate completeness as uncertainties can never be entirely eliminated. Results are therefore not meant to be adopted directly, and instead should be used to provide a range of possible future climate. Projection values are useful for guiding thinking and the overall impact assessment. Users should be flexible in their planning and adopt an adaptive management approach to allow for change as more information becomes available through observational-based monitoring, scientific research, and evaluation.

Photo: Workshop in Taunggyi, ASEAN DRR-CCA

Photo: Baseline survey in Taunggyi, ASEAN DRR-CCA

4 LANDSLIDE HAZARD AND SUSCEPTIBILITY MAPPING

Source: Project Team

Hazard is the main component of a risk assessment. As defined by the United Nations Office for Disaster Risk Reduction – UNDRR (formerly United Nations International Strategy for Disaster Reduction – UNISDR), hazard is a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Hazards can be caused by natural or anthropogenic activity. Natural hazards are predominately associated with natural processes and phenomena, while anthropogenic, or human-induced, hazards are predominantly the result of human choices and activities.

Landslide hazard refers to landslide probability (measured by area or volume) in a given location within a certain time interval (Crozier and Glade, 2012). Landslide susceptibility is used in place of landslide hazard in these guidelines as a complete landslide hazard analysis cannot be performed due to lack of data. These guidelines define landslide susceptibility as the propensity of a region for slope failure exposure (Hervals and Borowsky, 2009). Once required datasets become available, however, a full landslide hazard assessment is recommended.

The proposed landslide susceptibility methodology is a bivariate statistics analysis using weight of evidence (WOE) (**Figure 4.1**). This method relies on an inventory of landslide location. This inventory can be obtained from satellite images covering the study areas, such as RBPs in Laos and Myanmar. It is combined with parameter data such as soil texture maps, DEM, geological features, land use maps, road networks, and stream networks (**Figure 4.2**) collected from the relevant agencies and sources. The majority of the data used for this study is freely available from the public domain. In situations where resources are lacking, a statistical approach such as a landslide susceptibility analysis using a WOE approach can be used as long as the necessary data is provided. This method does not need a high degree of technical expertise as it is based on landslide inventories and is data driven. Though not difficult to learn, it nevertheless requires high data input accuracy. Data preparation, as explained in the previous section, therefore is crucial for this analysis.

Landslides are locally occurring phenomena that are usually associated with a trigger factor such as rainfall or an earthquake. When rainfall occurs, places in close proximity may have different conditions, for example, one slope may experience a slide while the adjacent slope remains stable. These heterogeneous conditions make landslide hazard prediction time consuming and very complex. Communities and districts with minimal human resources and expertise will need to find other simpler approaches that fit within these limitations.

Source: Workshop - Mapping Exercise in Taunggyi, ASEAN DRR-CCA

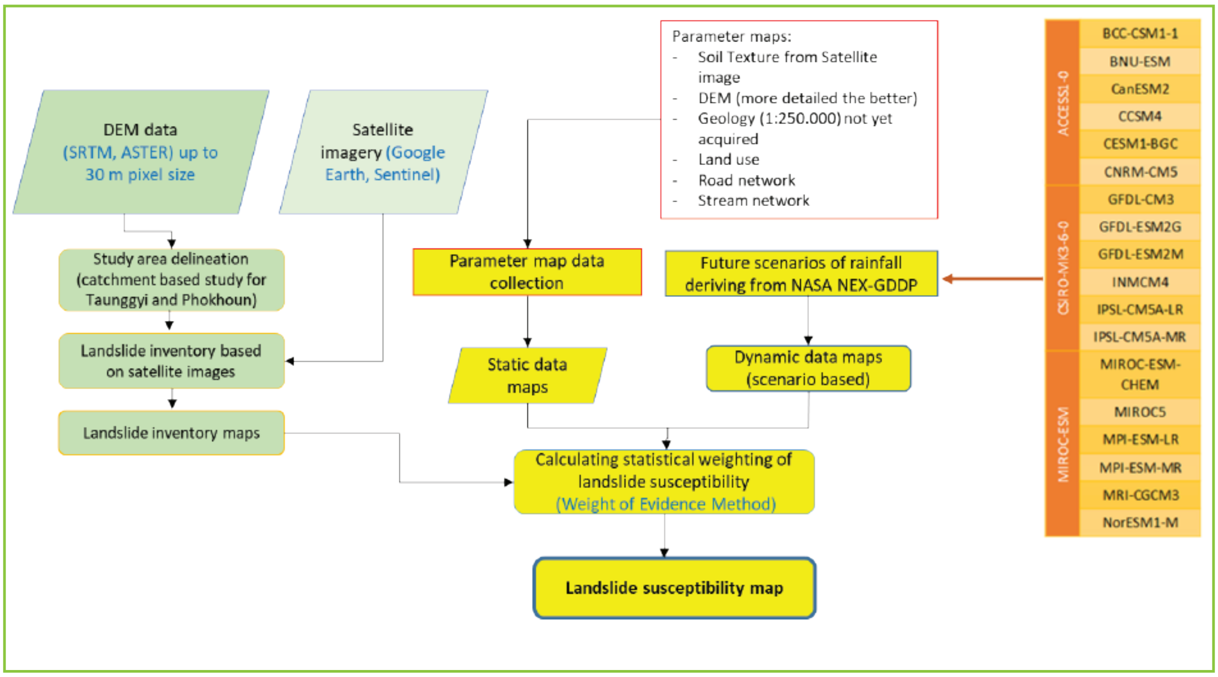


Figure 4.1 Landslide susceptibility analysis flowchart using Weight of Evidence (WOE)

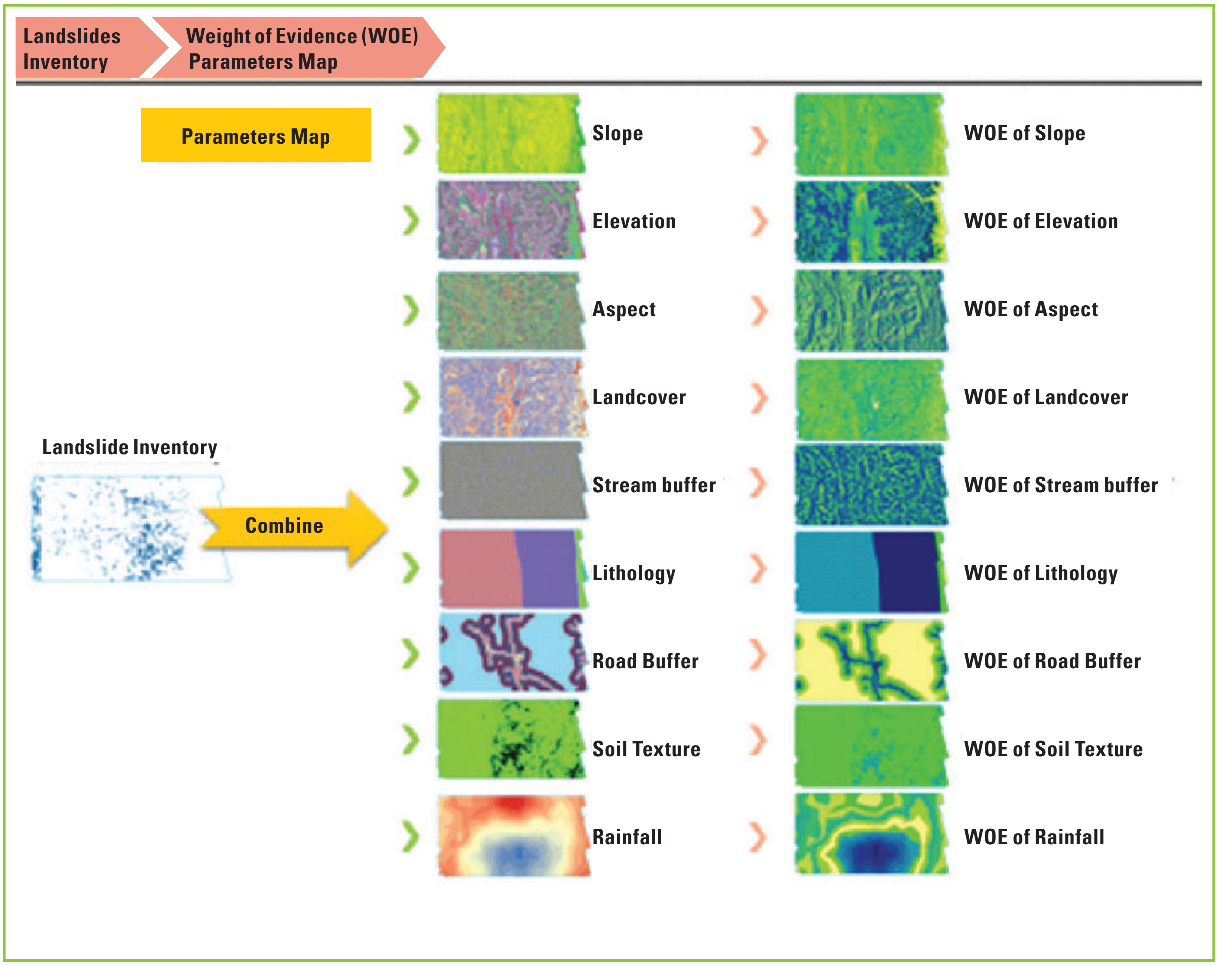


Figure 4.2 Sample of landslide susceptibility analysis parameters using WOE

4.1. Weight of Evidence calculation

Calculation of each particular predictive hazard variable involves assigning a positive weight (W+), when the event occurs and a negative weight (W-), when the event does not occur. The weights are measures of correlation between evidence (predictive variable) and event, making them easy to interpret in relation to empirical observation. Formulation is based on density functions. Weights (W_i) of each cell (i^{th} pixel) are determined by the equation:

$$W_i = \sum_{j=1}^{n} W_j^k$$

Where W_j is a parameter of the j^{th} class and w^k signifies positive and negative weight values. Controlling landslide factors can be mapped with this method. The weights can be used to produce a contrast value (C) for the specific susceptibility variable.

$$C = W^+ - W^-$$

The difference between weights (*C*) provides a measure of strength of correlation between the analyzed variable and the landslide. The RBP landslide risk assessment technical reports provide a more detailed landslide susceptibility method that uses weight of evidence.

4.2. Incorporating climate change model rainfall data

The proposed method should include both a historical perspective and climate projections for the future. Global and regional meteorological datasets can provide historical rainfall data, such as the Climate Hazard Group (CHG) CHIRPS 5x5 km^2 resolution precipitation data from 1981 to date, and the APHRODITE project 25x25 km^2 resolution precipitation data from RIHN/MRI/JMA from 1951 to 2007, as well as locally collected in-situ data. Landslide susceptibility (dynamic) mapping precipitation data projections can be derived from the NASA Earth Exchange (NEX) models covering the study areas for the following time periods: 2030s, 2050s and 2080s (15 days before and 5 days after peak rainfall during the monsoon season). The NASA Earth Exchange (NEX) models (CMIP5) that include future climate change scenarios from 21 Global Circulation Models (GMCs) under two emission scenarios (RCP 4.5 and 8.5) with 25x25 km^2 can be used as reference. **Figure 4.3** illustrates the landslide susceptibility mapping development process through incorporation of rainfall data derived from these climate change models.

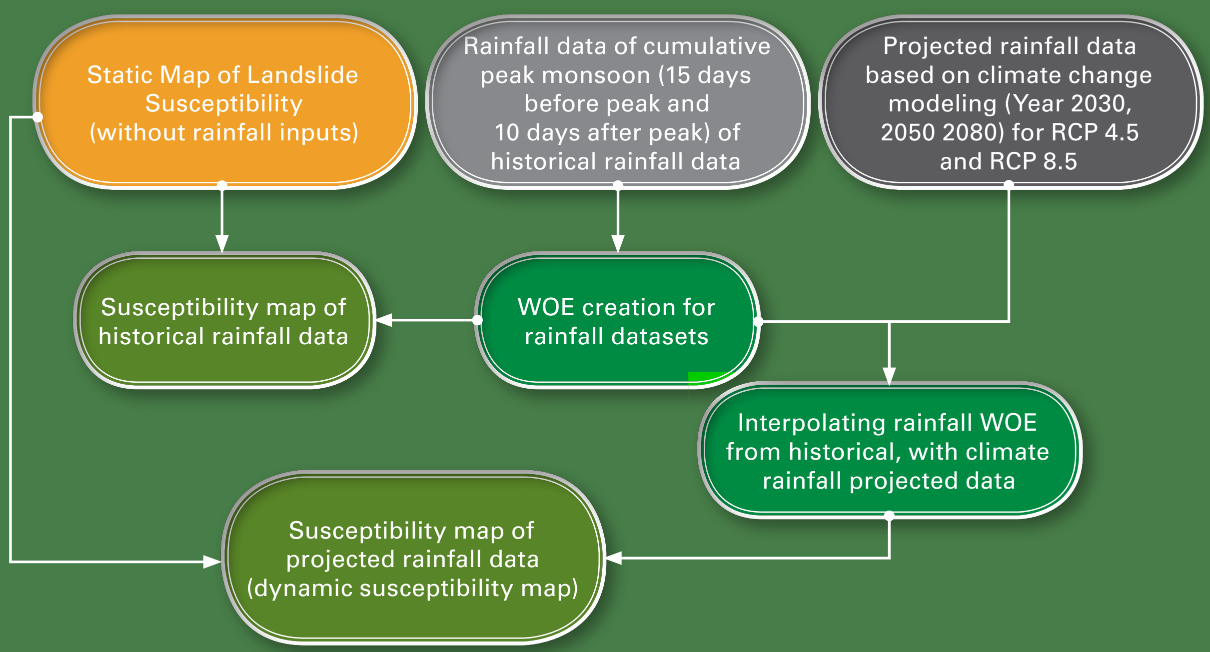


Figure 4.3 Process for incorporating rainfall derived from climate change models into landslide susceptibility

4.3. Landslide susceptibility map zoning

Susceptibility zoning uses GIS to overlay the WOE parameter maps. The overlaid map is first divided into approximately 255 classes (the more classes the better), at equal intervals from high to low WOE. These classes are then analyzed with a landslide occurrence using the raster analysis.

Based on the sorted classes, susceptibility zones are defined as follows:

- 50% of landslide occurrence is classified as *very high* zone
- 20% of landslide occurrence is classified as *high* zone
- 15% of landslide occurrence is classified as *medium/moderate* zone
- 10% of landslide occurrence is classified as *low* zone
- 5% of landslide occurrence is classified as *very low* zone

Figures 4.4 and **4.5** show an example of the landslide susceptibility map for the Taunggyi, Myanmar and Phoukhoun, Lao PDR RBPs.

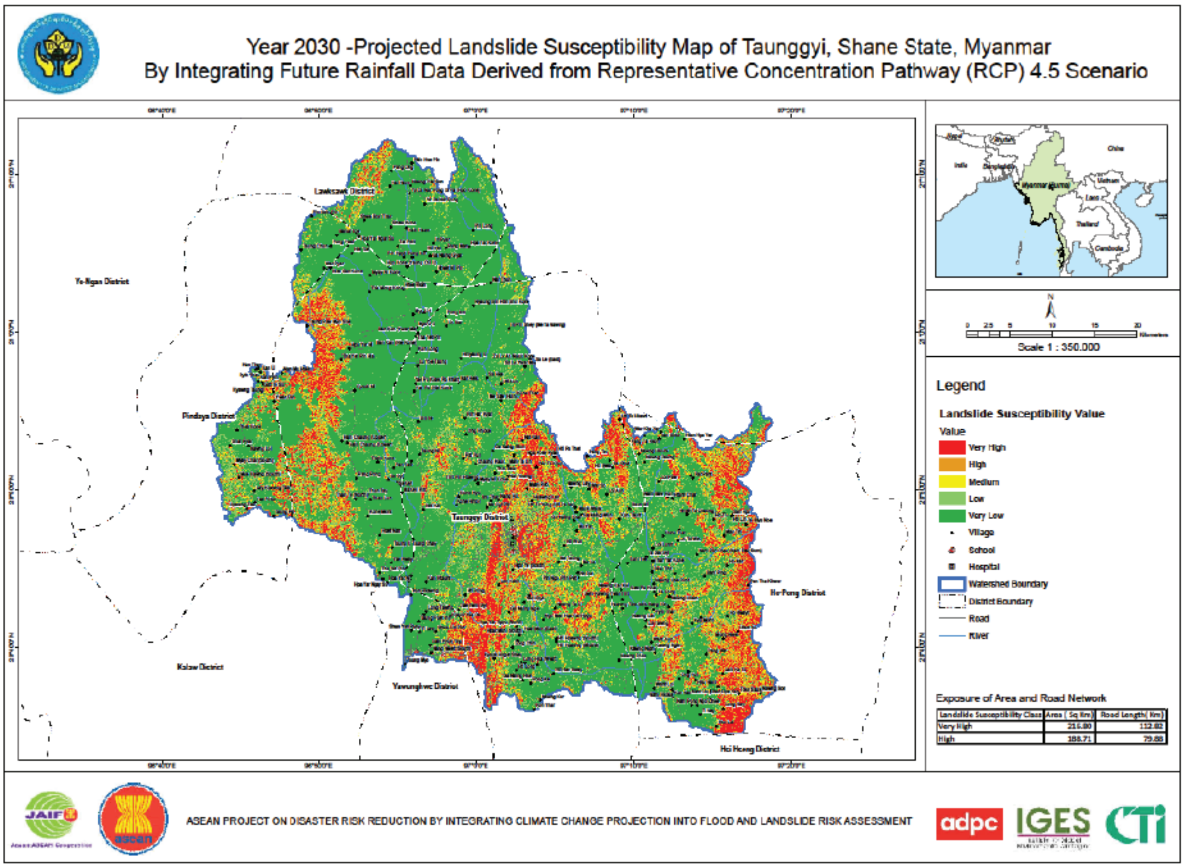


Figure 4.4 Taunggyi RBP, Myanmar landslide susceptibility map

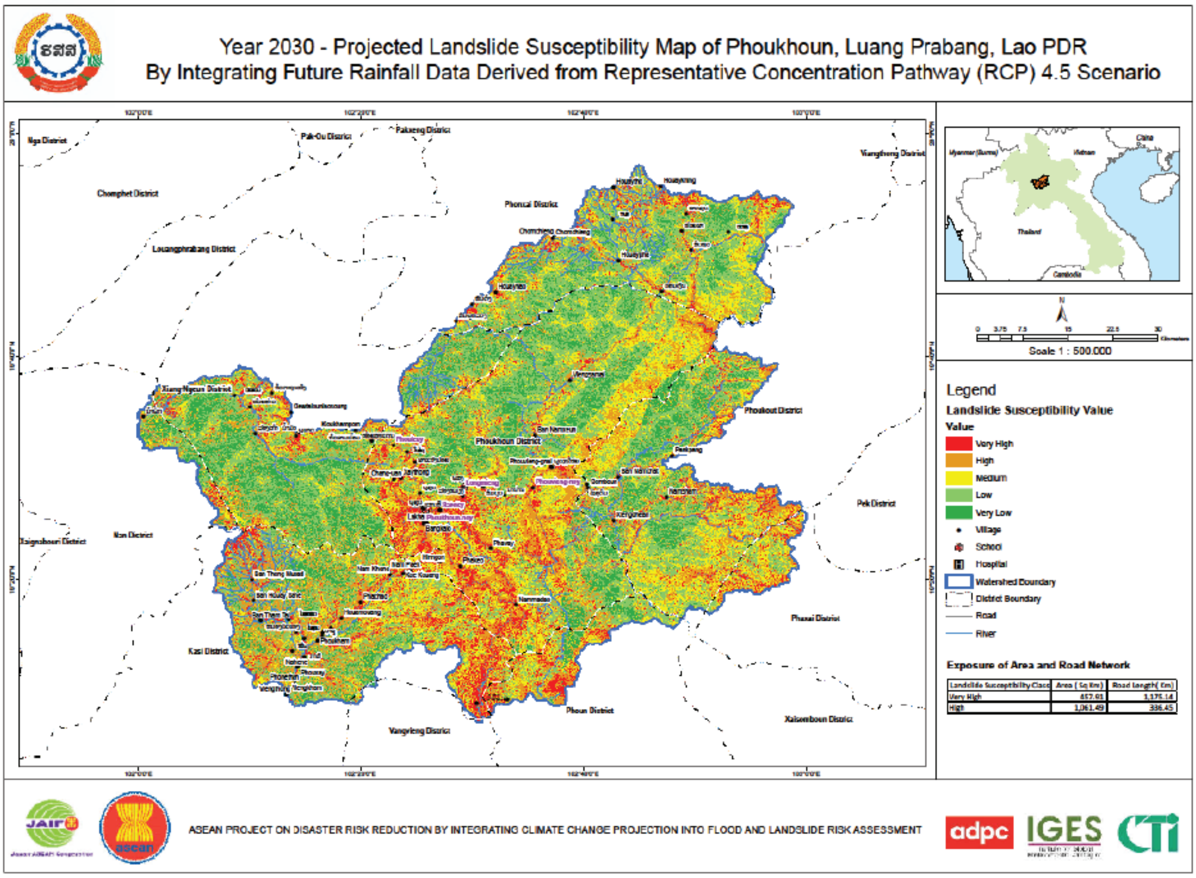


Figure 4.5 Phoukhoun RBP, Lao PDR landslide susceptibility map

Photo: Community-based disaster risk management exercise in Phoukhoun, ASEAN DRR-CCA


Photo: Taunggyi, ASEAN DRR-CCA

5 VULNERABILITY AND CAPACITY ASSESSMENT

Vulnerability and capacity assessment (VCA) is an important dimension of landslide risk assessment. There is no single assessment method, however, than can be applied due to both tangible and intangible damages. For example, loss of health, building and infrastructure damage and loss of income are categorized as tangible damages. Intangible damages, often referred to as non-economic damages, are those that cannot be reliably estimated or that do not have direct economic value in the market. This section covers assessment and estimation measures for both tangible and intangible damages. **Figure 5.1** below shows the VCA process adopted in the RBPs. Other landslide vulnerability methods will also be explained in this section. Guidance on their selection and use through RBP examples and existing documents such as the ASEAN Regional Risk and Vulnerability Assessment Guidelines is provided.

Figure 5.1 Vulnerability and capacity assessment process for landslide risk assessment adopted by the RPBs

5.1. Understanding the concepts

Vulnerability, resilience and adaptive capacity are three fundamental and vitally important concepts in climate change adaptation and disaster risk reduction. A good understanding of vulnerability and resilience is crucial to the development of sustainable adaptation strategies (Harley et al., 2008). The vulnerability concept took shape and gained greater attention among policy makers and development practitioners due largely to hazard and disaster risk reduction (DRR) work. However, vulnerability concepts have also been widely applied in other fields, including sustainable development, health, poverty reduction and environmental management.

The United Nations Office for Disaster Risk Reduction (UNDRR) defines vulnerability as "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard (UNISDR, 2015)." UNDDR further emphasizes that vulnerability can originate from a range of physical, social, economic and environmental factors. It is often regarded as the characteristics of the system of interest (such as a community or society or asset), and is independent of the exposure to which the system is subjected. These guidelines adopt this UNDRR vulnerability definition.

Vulnerability can be understood as a concept, a state of a system and a process (Prowse, 2003). As it recognizes and captures changes happening around the system in question, it can be considered a dynamic concept. As a state, vulnerability can be understood as the condition that predisposes a particular system to be affected by hazards. Vulnerabilities can also emerge due to processes operating within or beyond the vicinity of a society, but are not necessarily caused by the society itself. For example, a village situated near a mine is vulnerable to a variety of impacts due to mining activities happening in its vicinity, even though the villagers may not engage in mining directly. Mining pollution and other health issues could predispose the villagers to the impacts of an impending natural hazard. Vulnerability factors could therefore

Photo: Risk and vulnerability assessment - household survey in Taunggyi, ASEAN DRR-CCA

be intrinsic to a system as well as exogenous to it, regularly testing its ability to withstand external pressures. Vulnerability can manifest in economic, social, institutional and natural (biological, biophysical and environmental) systems with which communities interact regularly.

Exposure refers to the physical, social and natural elements that can incur potential losses due to a hazard and to which people and infrastructure are exposed. In these guidelines, the exposure concept is defined as natural disaster severity in terms of magnitude, duration and frequency to which physical, social and natural elements are subjected. Exposure differs from hazard to hazard. For example, droughts normally do not cause physical infrastructure damage while floods, landslides and typhoons do. For quantification purposes, exposure can be considered as all physical, social and natural elements – irrespective of their socio-economic and physical condition – present in an area where a hazard may occur.

Sensitivity is defined as "the degree to which a system will respond to a given change in climate, including beneficial and harmful effects" (McCarthy et al., 2001). Sensitivity is the major factor that determines the consequences of natural hazard exposure. Elements that predispose the system to losses from a hazard determine its sensitivity. For example, a household dwelling in a low-lying area that suffers from poor disaster preparedness will be severely impacted by landslides, as opposed to a household dwelling in the same locality in an elevated area that has adequate preparation. Similarly, all households in a landslide area are not equally impacted by landslide, rather impacts differ according to the socio-economic conditions that define their predisposition to hazard impacts. Though exposure is an important determinant, it is not sufficient on its own to measure disaster impacts (Cardona et al., 2012). For example, communities in low-lying areas can have higher flood sensitivity compared to those living in elevated areas, but in addition to low lying areas, other predisposing factors can also include poor transportation and lack of disaster preparedness.

Sensitivities do not translate into impacts unless a hazard event such as a flood or landslide happens. Therefore, vulnerabilities are realized only when hazards meet sensitivities. As a result, sensitivities, and hence vulnerabilities, can be masked for several years until a hazard occurs and can take a community and other actors, including local governments and non-governmental organizations and individuals, by surprise. This is where conducting regular vulnerability assessments could help to unearth 'hidden vulnerabilities' before hazards occur so that both preparedness and mitigation measures can be adopted to address potential impacts. From this point of view, it is important to factor in climate change when estimating vulnerabilities. Knowledge on how hazards, sensitivities and capacities change as a result of climate change and associated variability is also essential.

Adaptive capacity refers to the ability of an entity to address negative disaster impacts, including the ability to harness climate change impacts for benefit.

Adaptive capacity can be considered a counter to sensitivity and may address sensitivity factors. For example, factors such as the presence of strong social bonding, protective natural vegetation and strong leadership can reduce landslide impacts in a range of time scales. Not all capacities can be mobilized at the same time. The more immediate the capacity is to a community, both in terms of geographic and time proximity, the sooner the community can utilize it and potentially mitigate impacts.

Figure 5.2 illustrates the relationship between exposure, sensitivity, adaptive capacity and net impacts. Community response after an event such as a landslide is a result of the interaction between hazard, exposure, and sensitivity. Potential hazard impacts are based on exposure element sensitivity. Net potential impacts are a result of system adaptive capacity. If adaptive capacity is low or does not exist, net impact could equal potential impact. Risk assessments often calculate likely potential impacts. This could include either net impacts or potential impacts, depending on how the risk assessment is designed. If the risk assessment considers community and institutional system adaptive capacity, the assessed risks are equivalent to net impacts. If the risk assessment does not consider adaptive capacity, which is often the case as capturing this in quantitative terms is not a well-established practice, the assessment will express potential impacts. Adaptive capacity plays a vital role in how a system is impacted after a hazard event. Therefore, adaptation intervention design should not only be based on sensitivity assessment but also capacity assessment: existing capacity and outside capacity that can be readily and quickly mobilized. The methodology developed for an assessment would additionally have to take existing capacities into consideration.

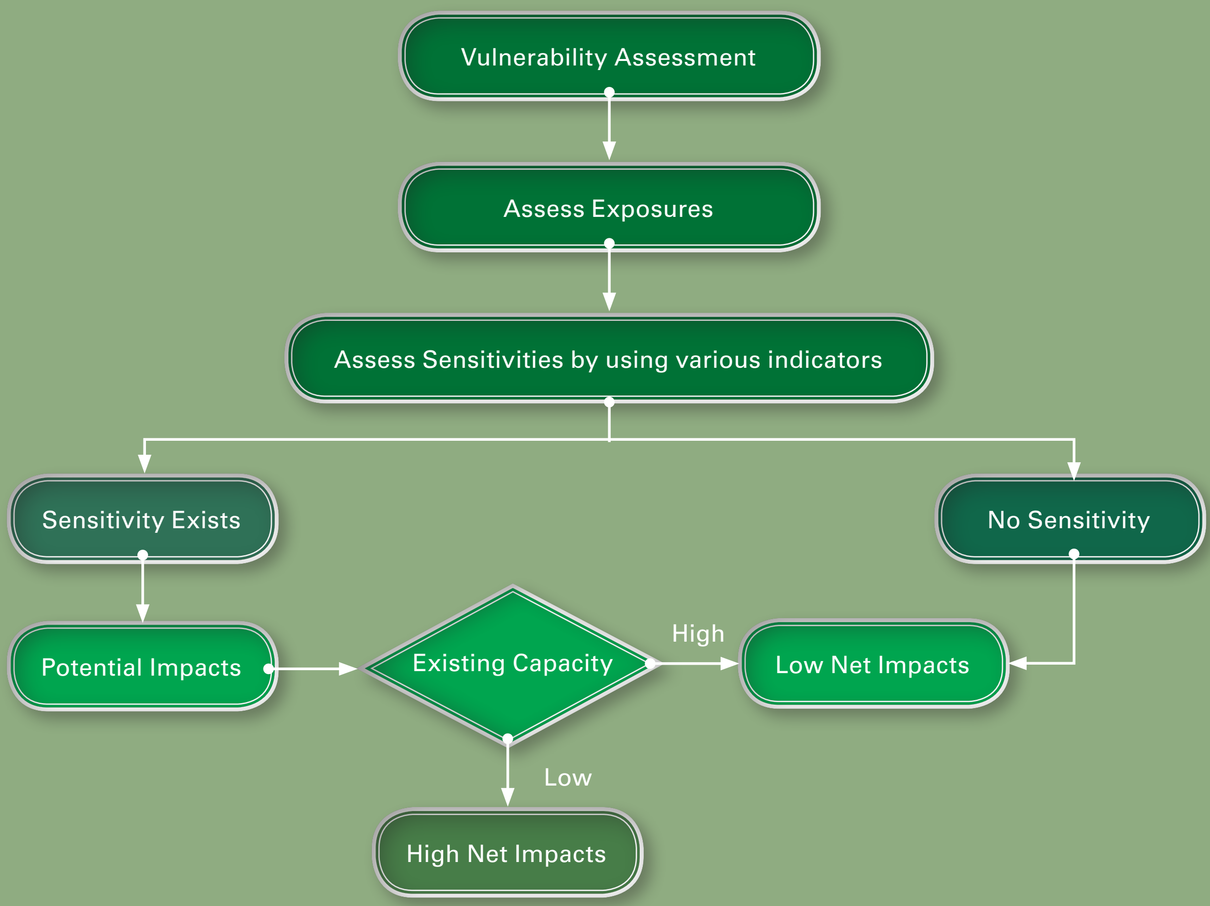


Figure 5.2 The relationship between vulnerability, adaptive capacity and net impacts (modified by workshop participants, based on Prabhakar, 2013)

Vulnerability can also arise from loss of resilience in a system due to the dynamic nature of natural hazards associated with climatic variability and change, as well as system socio-political drivers. Increasing system resilience can therefore help reduce vulnerability. Embedding resilience indicators in vulnerability assessments is important. Resilience defines capacity to cope beyond the minimum. A resilient community is able to return from a shock to previous or prevailing conditions.

Adaptation is an effort or action toward reducing negative climate change impacts (Keithley and Bleier, 2008). The adaptation concept cannot be realized through project design and implementation alone, as it also must help reduce vulnerability and build resilience. Vulnerability often comes to the forefront of discussion when addressing climate change adaptation (SPREP, 2009).

Climate change impacts can be reduced by: (1) promoting resilience to reduce system sensitivities, (2) increasing adaptation capacity and effectiveness of adaptation responses, and (3) improving adaptation planning processes (Grafton, 2009). The graphs in **Figure 5.3** below illustrate vulnerability, resilience and adaptation situations. A landslide can affect poor household wellbeing or the community at large. A vulnerable community may not be able to return to its original wellbeing level (graph 1). The first graph in **Figure 5.3** is a typical example of a vulnerable household or community that is prone to climate change risk. Any disruption in the climate system would lead to overall wellbeing decline.

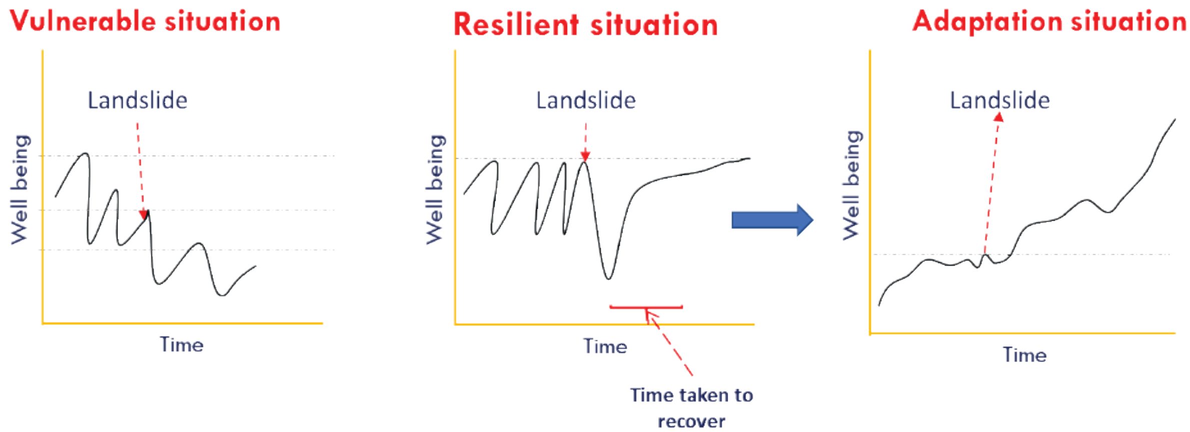


Figure 5.3 Hazard vulnerability, resilience and adaptation situations (Source: Adapted from Ilori and Prabhakar, 2014)

Graph 2 in **Figure 5.3** shows that a resilient community will be able to bounce back from a climate disaster. The degree of resilience can determine the speed with which a household or community can return to their original wellbeing level. As the climate changes, strong resilience therefore becomes an important asset. Resilience indicates that declines due to landslides are only temporary, with the system returning to normal after a certain period of time.

Graph 3 illustrates a typical household or community that has moved beyond resilience to being able to fully adapt to a new climate. In this scenario, landslide events are shorter and do not significantly change wellbeing. Interventions such as appropriate land use techniques or an early warning system helps individuals and communities fully adapt to landslides.

Vulnerable communities impacted by climate change will not be able to return to previous conditions without external intervention. An adaptation intervention serves to move people and communities from a vulnerable situation to a resilient or adaptation situation.

Vulnerability knowledge is key to understanding landslide damages and their underlying causes. A risk reduction strategy without a vulnerability assessment provides an incomplete picture of system risk exposure. System vulnerability is comprised of various physical, social and environmental elements that also include institutional and policy aspects. Vulnerability assessments can therefore be very complex as they contain both qualitative and quantitative aspects. Not all vulnerabilities can be quantified in the same way as crop loss or building damage. Crops and buildings have clear market value that can be assessed at a given point in time. Vulnerability assessments can therefore become cumbersome when physical elements are mixed with institutional, policy and social elements. However, as these elements play a vital role in measuring community vulnerability, they cannot be ignored. Decision makers insist on a complete vulnerability picture. Combining physical with institutional, policy and social elements is challenging, so both qualitative and quantitative vulnerability assessments must therefore be robust. Risk assessments based on physical elements alone will not reveal a community or region's full risk spectrum and hence can misrepresent overall risks.

To address the limitations discussed above, a vulnerability assessment can be divided into quantitative and qualitative elements. A quantitative vulnerability assessment includes sensitivity factors that can be readily assessed quantitatively in economic terms or physical terms such as crop loss per hectare ton. These factors can be determined using loss and damage data collected by the local government in the immediate disaster aftermath, or through interviews and data collection surveys in the affected communities.

A qualitative vulnerability assessment is a comprehensive study that includes elements that cannot be quantified by economic or other means but that have some assigned value according to proxy scales, such as the Likert scale (a qualitative positive and negative scale for measuring respondent choices). A combination of qualitative and quantitative vulnerability factors in a representative index (which is a unit-less value) completed through data transformation techniques can be used to compare vulnerabilities in several localities. This index, when accompanied with quantitatively assessed risks, can provide a more valuable overall picture of risks and vulnerabilities faced by communities and regions, as opposed to using only quantitatively assessed risk alone. The qualitative section of the vulnerability assessment can be documented using an Excel file, allowing the user to easily rank specific indicators and assess vulnerabilities relatively quickly.

5.2. Why conduct vulnerability assessments?

Climate change vulnerability assessments are important in adaptation planning as they help governments, funding agencies and local stakeholders prioritize geographical areas, vulnerable communities and projects while recognizing limited available resources for adaptation investment. Vulnerability assessments additionally provide the means to measure progress in achieving adaptive capacity and help with decision-making in both ex ante and ex post implementation of adaptation projects.

Vulnerability assessments provide deeper knowledge of risk manifestation mechanisms, and ultimately losses, when a hazard strikes. Without deeper vulnerability understanding, risk reduction strategies may not be effective as they tend to fail in addressing underlying causes behind risks. A vulnerability assessment can also help assess sectoral vulnerabilities and cumulative vulnerability for design of specific interventions.

Experience suggests that the majority of vulnerability assessments result simply in identifying vulnerabilities, and that there is a significant schism between vulnerability assessment outcome and intervention design. Vulnerability assessments often provide only a narrative background and are ignored at the risk reduction intervention stage. While this is usually due to project design and scoping approaches, it also reflects the fact that methodologies have not been fine-tuned enough to provide usable information for identifying project interventions. For example, a vulnerability assessment may identify a host of socio-economic factors that may be ignored in a project or program where the major intervention is in the form of infrastructure design. While it could be claimed that the infrastructure intervention will address socio-economic vulnerabilities, it happen over a long period of time. Risk reduction benefits could be more immediate if the project explicitly addresses socio-economic aspects from the beginning.

Vulnerability methodology development should also take the needs and necessities of concerned stakeholders into consideration. The methodology should consider the capacity of institutions that execute the adaptation projects, and be suitable to different project types. Finally, a vulnerability methodology should inform diverse users on risk reduction tools and approaches. Risk reduction approaches come in different forms and shapes, ranging between highly technological infrastructure interventions to nature-based and social and institutional interventions. Mixed risk reduction interventions that use a combination of these approaches are common. It is therefore important to recognize that risk reduction projects are implemented in a wide variety of ways using various means. Developing a vulnerability reduction methodology to suit to such a diverse context can be challenging. Achieving maximum efficiency in terms of stakeholder agreement and uptake requires an understanding of methodology context. The methodology should be practical and usable in the context in which it is employed.

5.3. Unified methodology need

In the context of climate change, there are different views on what constitutes a vulnerability assessment. As a result, literature on the topic employs a range of quantitative and qualitative, as well as a combination of, methodologies. Vulnerability assessment methodologies have been developed to suit several different typologies, including geographical (watersheds, river basins, forested areas, rural and urban areas), political boundaries (at national, subnational and village levels), and sectors (agriculture, urban infrastructure, transportation, health, etc.). Vulnerability assessment methodologies are adopted on the ground to suit assessment purpose and location-specific capacity considerations. In general, vulnerability assessment methodologies tend to be complicated as they need to consider vast complexities manifested on the ground.

The International Standards Organization (ISO) has recognized that a variety of vulnerability assessment methodologies have been developed for a wide variety of contexts, and the need to standardize these methodologies so that they can provide some degree of comparability across geographic and time scales. It has initiated a process to develop a standard for vulnerability assessment for climate change adaption planning. The ISO/AWI 14091 *Climate Change Adaptation – A Guidance to Vulnerability Assessment* aims to provide guidelines to practitioners, including planners and development professionals engaged in designing and implementing climate change adaptation projects and programs. However, this process started in September 2017, and the guidelines will not be ready before finalizing the methodology for this project. The experiences generated in this project can therefore provide useful inputs to the ISO process.

While there are many conceptual factors underpinning climate change vulnerabilities, there are also diverse adoptions of these concepts on the ground. It is important to consider taking stock of the strengths and weaknesses of these experiences before building a vulnerability assessment methodology. The methodology in these guidelines therefore refers to work that has already been done, in particular work identifying suitable flood and landslide vulnerability indicators and that which covers rural backgrounds, watersheds and river basins.

Using the above-mentioned methodology history, this document provides a succinct review of existing vulnerability assessment methodologies, assesses the limitations and potential advantages they offer, and proposes an appropriate methodology that is stakeholder inclusive. The assessment methodology in these guidelines also reflects user capacity and scenarios at the time it was developed. It therefore may not satisfy multiple criteria of typical vulnerability assessment methods. However, users can easily employ and continuously improve it as new vulnerability assessment knowledge emerges.

5.4. Vulnerability assessment methodologies

Understanding current vulnerability assessment approaches

The vulnerability concepts discussed earlier in this section have been applied in different contexts, resulting in creation of several assessment methodologies. An examination of these methodologies reveals the following conclusions. Understanding these conclusions helps to identify the right methodology for the project.

1. All methodologies, whether qualitative or quantitative, have used the exposure, sensitivity and capacity model for vulnerability assessment. The majority of vulnerability assessment methodologies have used participatory approaches that involve communities at the local level. These approaches employed a variety of tools. For example, tools such as seasonal calendars, historical timelines and rain calendars were used for assessing exposure. Tools such as hazard mapping, mental models, hazard trend analyses and ranking, as well as a hazard impact livelihood matrix, were used for assessing sensitivities. Tools such as social maps, resource maps, Venn diagrams, preference ranking, wealth ranking, communication maps, and vulnerability and capacity matrixes were used for assessing adaptive capacity (refer to **Annex 7** for a brief explanation of these methodologies). These tools, however, are applied by varying degrees to the different methodologies, depending on author expertise and location-specific conditions.
2. Though the majority of vulnerability assessments follow the exposure, sensitivity and capacity model, for those that are qualitative it is difficult to determine the severity of vulnerabilities at one location compared with those at another location. Lack of simple quantitative methods makes it difficult to prioritize the nature and severity of vulnerabilities.
3. Most methodologies tend to identify vulnerabilities through indicators that are not often quantified.
4. The distinction and use of both the biophysical and socio-economic vulnerability indicators identified in most methodologies is not clear.

5. Climate change adaptation options suffer from weak linkage between, and use of, vulnerability and quantification information. Adaptation option identification therefore appears to be isolated, both in terms of process and vulnerability linkage, from the balance of assessment methodologies and outcomes.
6. Methodologies that did not identify change as an indicator were mainly limited to general indicators such as temperature and precipitation.
7. There is wide variation in the nature of indicators representing sensitivity and capacity. The majority of indicators used were broad demographics and socio-economic classifications such as income and education levels. These indicators can be obtained from the village level and other census data.
8. Future projected climate change impacts are featured in the majority of assessment methodologies. However, DRR and CCA practitioners are also cautioned about overemphasis on projection-based vulnerability assessments in general. The recently released vulnerability assessment report from the Institute for Social and Economic Transformation, part of the USAID Mekong Building Climate Resilience in Asian Cities (M-BRACE) program, concluded that overemphasis on future climate projections could potentially make interventions too narrowly-based. This narrow approach may have a higher chance of failure due to the uncertainty associated with future climate projections. Instead, it is advised in this project to focus on processes on the ground and recognize local capacity by employing a participatory approach involving multiple stakeholders. With this local approach as a starting point, future projections can be introduced later as an increasing number of stakeholders understand the language of climate projection and corresponding uncertainties (Institute for Social and Environmental Transition, 2014).

The above discussion demonstrates that identifying and quantifying indicators in current vulnerability assessment methodologies is important. Indicators provide a straightforward way to grasp different vulnerability assessment components and show how they relate to each other in the final assessment outcome. The majority of assessments, including the Human Development Index and those carried out by multi-lateral development agencies such as the World Bank, Asian Development Bank and the UN, employ indicators to track development activity progress. Census records, sample surveys and other publicly available sources can provide data for the majority of commonly used indicators. The proposed methodology for this project also provides a degree of flexibility so that certain types of indicators for which data is not available can be obtained through measurement, estimation or by use of proxy indicators.

The need for using indicators in vulnerability assessment is supported by DRR scholars such as Vincent and Cull (2014), who state that "in social, or context vulnerability, vulnerability is a potential state that determines whether hazard exposure will translate into adverse impacts. It is therefore necessary to rely on indicators that best represent the complex underlying processes." DRR studies employing indicators identified them either through an inductive or deductive approach. An inductive approach selects vulnerability indicators from a wide variety of indicators. For a deductive approach, indicators are often chosen through a theoretical framework that is constructed to explain underlying vulnerabilities. Inductive approaches are often data-driven and intensive. Final indicator identification in inductive approaches is a result of either thorough expert judgment or a multi-criteria analysis. Indicators are often combined to form indices.

Several international disaster risk assessment indicators developed by the World Bank, UNDP and Inter-American Development Bank (IDB) may be useful as metrics for monitoring climate change adaptation and climate change progress. For example, the Disaster Risk Index (DRI) developed by UNDP and the hotspots index developed by the World Bank are deductive[1] and built on theoretical constructions of vulnerability that are then populated with existing secondary data. They both aim to show human disaster risk vulnerability. Changing vulnerability levels over time might indicate adaptation action implementation and/or effectiveness. The DRI and hotspots indicators have national and sub-national resolutions, respectively, and both calibrate vulnerability indexes against disaster loss. This adds rigor, but it also means measures are retrospective in nature and are dependent on the quality of externally-derived input data. The key advantage of these methods is that they are centrally-managed, providing cost and quality control, and are easily repeatable over time and space (Pelling, 2008). The key limitations are that associated models follow theory, not data, and data and output resolution coverage and quality are set externally. They are also tied to historic and current vulnerability snapshots, but not future vulnerability.

Understanding impact pathway indicators

1 Deductive refers to a reasoning scenario wherein real-world observations are explained based on a single theory or set of theories. It differs from the inductive approach, wherein generalizations are made based on a set of observations.

Figure 5.4 shows the path along which climate change impacts the local agricultural economy and subsequently the larger economy. This pathway can provide a valuable foundation for identifying and narrowing down specific vulnerability indicators. The figure shows how vulnerabilities along the impact pathway line exacerbate disaster impacts.

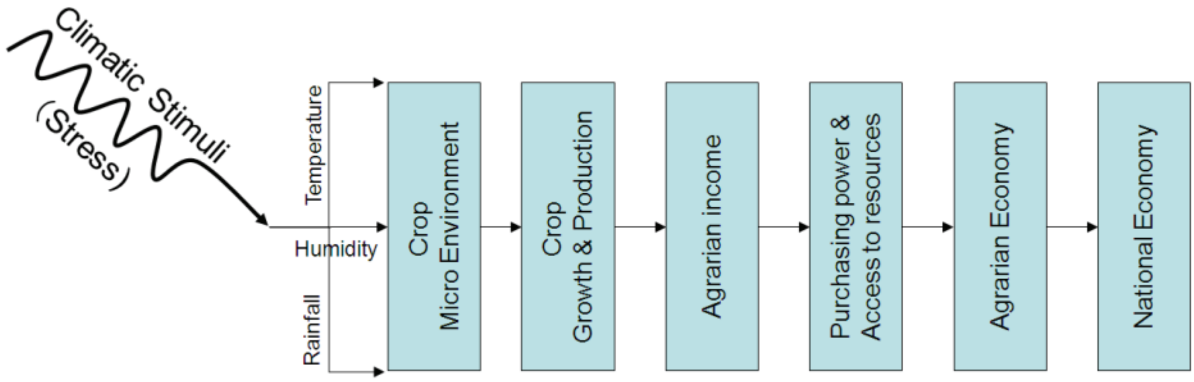


Figure 5.4 Climate change impact pathway for agriculture and macro-economic linkages (Prabhakar et al, 2010)

The impact pathway concept provides the following knowledge that helps in identifying vulnerability indicators.

1. Addressing vulnerability diversity assumes importance as environmental or biophysical vulnerabilities can lead to vulnerability in individuals. This is especially true for those that depend on natural resources for their livelihoods, which is common in agriculture and other rural-based livelihoods.
2. Similar to how natural resource vulnerability leads to vulnerabilities in individuals, vulnerability in individuals can result in collective or social vulnerabilities. Both individual and natural resource indicators therefore must be considered.
3. The vulnerability assessment should have relevance to the same geographical boundaries and contexts in which adaptation projects are implemented due to the pathways through which climate change impacts agriculture and dependent livelihood elements.
4. Community-based approaches, especially those utilizing participatory rural appraisal techniques, can be useful in obtaining first-hand vulnerability information on individuals and societies.
5. Interaction between environmental and societal factors make it more likely that vulnerabilities in individuals and societies differ from location to location.

Landslide vulnerability indicator identification approach

Vulnerability assessment indicator development involves a series of consultative processes, as shown in **Figure 5.5**. Location-specific landslide vulnerability assessment indicator identification is important for the following reasons.

1. Indicators that are relevant at one scale or location may not be relevant at another scale. For example, the percentage of income from agriculture might be a highly relevant indicator in rural areas but not in urban areas.
2. Data availability: The extent of available data in government and other institution records could determine indicator inclusion.
3. Decision making needs vary at different levels due to differing indicators, though there may also be common indicators at different levels.

Vulnerability indicators can be identified through a literature review to understand how they were measured and used in other risk assessments. The review is based on risk assessment needs, the nature of the geographical area, socio-economic condition coverage and the target decision-making stakeholders. This initial indicator set may go through a series of stakeholder consultations made up of local communities, local, regional and national governments and other related stakeholders.

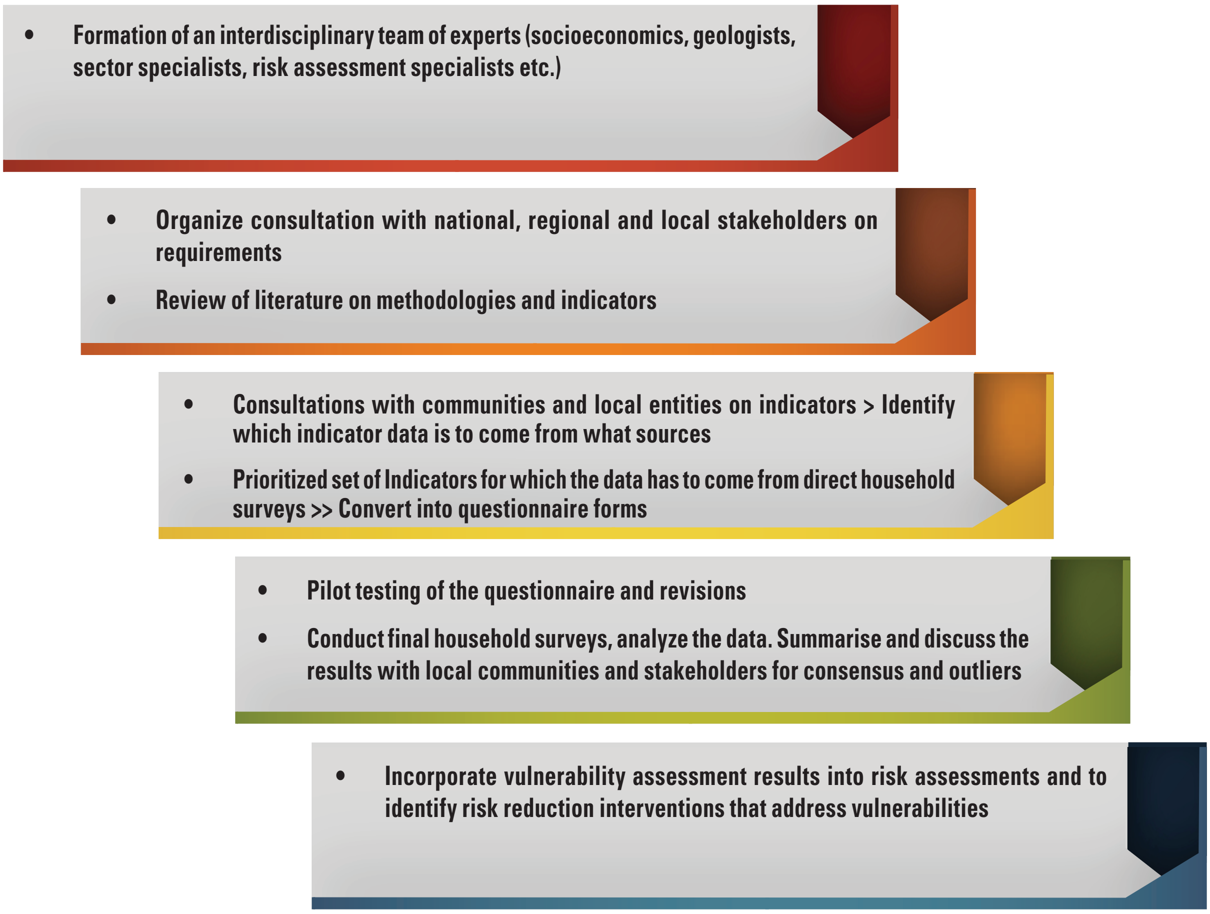


Figure 5.5 Strategy overview for vulnerability assessment methodology development

The literature review identifies a variety of indicators that must be vetted for vulnerability assessment appropriateness. To determine this, indicators should first be vetted at the community level through a participatory rural appraisal (PRA) exercise. Institution consultations provide feedback on approach appropriateness, indicator inclusion and sector focus, as well as the organization in terms of institutional and other stakeholder vulnerability assessment expectations. Subsequently, an indicator index can be developed for easy understanding and interpretation of vulnerability assessment output.

Vulnerability indicator typology

An extensive literature review can identify vulnerability indicators for further fine-tuning to the local-context. These indicators can be divided into several sub-categories based on economic sectors (**Table 3.1**). Common indicators capture nature-based vulnerabilities, or exposure indicators, as well as a diversity of other institutional and policy indicators that are sensitivity-based. Five sector-specific sensitivity indicators that capture vulnerabilities in natural, social and economic sectors are also included in the indicator typology. A different set of indicators captures individual or household capacity. For example, the food and agriculture category covers indicators related to agricultural cropping, soils, etc. Similarly, biodiversity indicators capture land-based and aquatic biodiversity and related ecosystem services. Detailed indicator lists of are provided in **Tables 3.2, 3.3 and 3.4**.

Table 3.1 Base categories for a prioritized set of indicators

Sector/Category	Number of Indicators
Common exposure and sensitivity indicators	64
Food and Agriculture	21
Water	24
Land	15
Fisheries and Animal Husbandry	15
Biodiversity and Ecosystem Services	13
Capacity Indicators	26

Indicator prioritization criteria

During the consultation process, the indicator list in Annex 1 must be prioritized according to the following criteria and approach.

- **Location-specific conditions:** Local context plays an important role in indicator precedence. Local consultations with institutional and community stakeholders are therefore key to understanding location-specific conditions and prioritizing indicators.
- **Causality and sensitivity:** While the majority of annex indicators contribute to flood and landslide vulnerability to some degree, not all of them contribute equally. Those that contribute the least can be removed from the list. A sensitivity analysis based on indicator priority can reveal the extent to which a particular indicator contributes to overall vulnerability.
- **Data availability:** Not all indicators are easy to acquire. Indicators for which data is available or that can be easily estimated or measured from direct data collection or secondary sources should be prioritized.
- **Collinearity and principal component analysis:** Vulnerability assessment literature suggests both collinear and principal component approaches for reducing the number of vulnerability indicators.

Table 3.2 Priority Socio-Economic Sensitivity Indicators

Indicator	Description
Family without educated members	Counts all households without an educated person. This household type has a landslide vulnerably scores (LVS) rating (landslide risk sensitivity).
Vulnerable population	Counts all households with a woman, child, and/or an elder older than 60 years. A household that satisfies at least one of these conditions is given an LVS rating of 1, two conditions LVS 2, and 3 conditions LVS 3. This data is then normalized to a 0-1 scale to combine with other indicators.
Female headed household	Counts households that do not have a living male elder. Given an LVS of 1.
Differently abled	Counts households with a physically disabled family member. Given an LVS of 1. This is in addition to gender and age considerations (for example a household with a disabled female will get two LVS values).
Poverty	Counts the monthly poverty income line. Households below the income poverty line are given an LVS of 1.
Access to Health	Counts the household's distance to a health center. Households beyond a 4.5 km radius from the health center are treated as sensitive, with an LVS of 1.
Home vacant time (HVT)	Counts amount of time during the day a household is vacant. Those with less vacant time are considered the most sensitive. Vacant hour values are linear and are given to fall within the LVS range of 0-1.

Indicator	Description
Rate of service interruption	Counts the average rate of service (such as water, electricity etc.) interruption (in percentage) with linear values and is given an LVS range of 0-1.
Interruption duration	Counts number of days of interruption (of water, electricity etc.) with linear values, and is given an LVS range of 0-1.

Table 3.3 Priority Physical Sensitivity Indicators

Indicator	Description
Slope of the land	Counts households located on a slope of greater than 15%. These are considered sensitive and are given an LVS of 1.
Living floor	Counts household living on the ground floor. This household type is considered sensitive (in accordance with earthquake literature), and given an LVS of 1.
Building age	Counts buildings more than 10 years old, given an LVS of 1.
Architectural Approval	Counts buildings without architectural/formal approval, given an LVS of 1.
Foundation type	Counts buildings that used clay aggregates or rubble in construction, given an LVS of 1.
Bedrock anchoring	Counts buildings with foundations reaching or anchored in bedrock and are given an LVS of 0 (not sensitive).
Nature of walls	Counts loadbearing wall structures, and given an LVS of 1.
Damage susceptibility rating	Self-assessed damage susceptibility ratings ranging between 1-10 are linear, normalized to LVS values.

Table 3.4 Priority Capacity Indicators

Indicator	Description
Disaster risk management participation	Counts households that have reported DRM participation, and given an LVS of 0.
Microfinance	Counts households that participate in microfinance programs, and given an LVS of 0.
Landslide discussions	Counts households that discuss landslides, and given an LVS of 0.
Migration readiness	Counts households that report having landslide preparedness measures in place, and given an LVS of 0.
Disaster risk management awareness	Counts households that expressed having disaster risk management awareness measures in place, and given an LVS of 0.
Alternative roads	Counts households that have more than one access road, and given an LVS of 0.

Computational methods

This section describes a basic approach for assessing vulnerabilities. Assessment methods are suitable for both business-as-usual (BAU) vulnerabilities as well as projected climate change vulnerabilities.

The vulnerability equation is:

Vulnerability = (E+S)-C ....**Equation 1**

Where:

E is the exposure value obtained by averaging the normalized exposure indicators.
S is the sensitivity value obtained by averaging the normalized sensitivity indicators.
C is the capacity value obtained by averaging the normalized capacity indicators.
The vulnerability capacity assessment index (VCAI) is computed using sets of indicators for quantifying index exposure, sensitivity and capacity components. The relevant indicators are presented in the next section.

Since indicators are measured using different scales with values that fall in different ranges, combining them to create an index requires their conversion into a unit-less value. This is achieved by normalizing the values using a linear normalization technique.

The equation for normalizing indicator values is:

$$z_i = \frac{x_i - T_{\min}(x)}{T_{\max}(x) - T_{\min}(x)}$$

....**Equation 2**

Where:

Z_i is the normalized indicator value.
x_i is the indicator value.
T_{min} is the minimum threshold value of indicator x_i.
T_{max} is the maximum threshold value of indicator x_i.

Exposure (E) is calculated as the average of normalized exposure indicators as prioritized and measured by the user. The equation for Exposure is:

$$\text{Exposure (E)} = \frac{\left(\sum_1^n i_{ne}\right)}{n}$$

................................**Equation 3**

Where:

n is the number of exposure indicators chosen for the vulnerability assessment.
i_{ne} is the exposure indicator normalized value.

Sensitivity (S) and capacity (C) are calculated with a set of indicators categorized into six sectors: 1) Social, institutional and policy dimensions, 2) Agriculture and food, 3) Water and sanitation, 4) Land and infrastructure, 5) Fisheries and animal husbandry, and 6) Biodiversity and ecosystems, including forests. Sensitivity computation comprises taking the average of the normalized indicator values from these six sectors. A similar methodology was used for computing capacity.

The equation for sensitivity (S)s:

$$\text{Sensitivity (S)} = \frac{S_s + S_a + S_w + S_l + S_f + S_b \ldots S_n}{n_a}$$

..............................**Equation 4**

Where:

S is overall sensitivity
S_s= Social, institutional and policy sector sensitivity.
S_a = Agriculture and food sector sensitivity.
S_w = Water and sanitation sector sensitivity.
S_l = Land and infrastructure sector sensitivity.
S_f = Fisheries and animal husbandry sector sensitivity.
S_b = Biodiversity and ecosystem (including forests) sector sensitivity.
n_a = Total number of sectors for which sensitivity is assessed.

The description will be added.

$$\text{Ss} = \frac{\left(\sum_1^n i_{ns}\right)}{n_i}$$

....**Equation 5**

Where:

n_i is the number of sensitivity indicators chosen for the sector vulnerability assessment.
i_{ns} is the sensitivity indicator normalized value.
A similar approach was used for computing the VCAI capacity (C) component.

Landslide vulnerability scores

Landslide vulnerably scores (LVSs) are a qualitative method of assessing individual household landslide vulnerability. The individual indicator is assigned a score of 0 or 1 (with 0 representing no vulnerability and 1 representing high vulnerability) based on household condition data from the questionnaire survey. This binary scoring represents whether a particular condition is satisfied by the household. However, more nuanced ternary or quaternary (0, 1, 2, 3 or 0, 1, 2, 3, 4) scoring is also possible to increase analysis resolution.

Assigning LVSs: Literature, for example that which concludes that poverty plays an important role in determining disaster vulnerability, and expert judgement provide the basis for assigning LVSs. Structural element resistance factors can be used for assigning the scores. For example, concrete structures have higher resistance to landslides than other structures. If the study location lacks assigned resistance factors, landslide literature available elsewhere can be used to assign ratings to different structural elements. For example, a reinforced concrete building is considered to have a high resistance factor compared to stone masonry structures, loadbearing structures, etc. Recent reinforced concrete construction (less than 10 years old) is considered to have higher resistance than older construction. All reinforced concrete buildings that are less than 10 years old can therefore be given a zero rating, with those above 10 years given a 1.

Mutual dependency and indicator hierarchy

As indicators, mutual dependency and hierarchy can overlap. For example, recent reinforced concrete construction that has a shallow foundation or does not satisfy the basic condition of anchoring to bedrock can be more vulnerable to damage than other types of framed structures, such as bamboo, that are anchored. Similarly, when official building design approval is included as an indicator, it could essentially include other indicators such as foundation depth. These interdependencies were not considered for this project analysis, but any that are detected as a result of the methodology can be recognized to avoid over estimation. It is important that these mutual dependencies are assessed in advance and treated appropriately wherever possible.

Assigning weighting to overall vulnerability contribution

Not all indicators and vulnerability sub-components contribute equally to overall vulnerability. For example, education is important, but lack of education may not contribute to overall vulnerability compared to an indicator such as preparedness planning. Weighting will recognize these differing contributions for a more accurate picture of overall vulnerability. To avoid generalization, weighting needs should be determined through consultation. The project considered weighting by inviting the experts that participated in project workshops and training sessions to provide weighting to indicators. These weightings were used in the methodology. The weighting exercises were carried out by providing the experts with the indicators list and organizing break out group sessions where experts deliberated in detail in regard to how each indicator contributes to overall vulnerability. Based on consensus, the group then decides a weighting value for each indicator. Multiple values received from multiple groups are then discussed in a plenary and a single value is obtained by consensus through a workshop discussion. For weighting exercises to be robust, following this elaborate process is recommended.

Photo: Risk and vulnerability assessment - household survey in Phoukhoun, ASEAN DRR-CCA

Derived and proxy derived indicators

Derived and proxy derived indicators are used for the project vulnerability assessment to increase original indicator relevance. For example, the distance to a health care center – an original indicator used in the household surveys – was converted into minimum response time equivalent distance. The conversion indicated that vulnerability is higher when the difference between actual distance and minimum response time is higher. This type of conversion recognizes that distance itself is not a sufficient determinant of vulnerability. Travel time plays an important role as well. In another example, the number of people at home is converted into household vacant time, to suggest that households with the least vacant time are highly sensitive to landslide risks.

Assessing future vulnerabilities

Assessing vulnerabilities in a business-as-usual scenario is straightforward, using a set of measured or computed indicators for historical or present values. Socio-economic vulnerability projection for a given future period, however, is riddled with uncertainty as it necessitates interaction between future climate and population trends, in addition to future socio-economic developments. Macro-level vulnerability projection at national and sub-national levels is relatively easier than projection at a river-basin or household level, for example, as uncertainty factors proliferate at these more local levels.

As there is no single model that can accurately project different vulnerabilities and indicators at the household level in a future climate change context, vulnerability projection should include a mixed methods approach. For example, downscaled future GDP values, crop production, etc. are widely available, while information on other socio-economic wellbeing categories is largely missing. To overcome this limitation, a combination of the following approaches can be employed.

- **Driver projection:** Projections for drivers such as population growth, urbanization, demographic characteristics and technological trends are widely available and provide valid beginning points for vulnerability extrapolation. Projected drivers can serve as useful base values in combination with the impact chains approach discussed below.

- **Impact chains:** Impact chain building (**Figure 5.6**) can help narrow down appropriate indicators and their values in a future climate scenario. Impact chains, in combination with expert judgements, provide a structured approach to visioning the future. Impacts can interact with each other and produce several secondary impacts that are either similar in nature or generate multiple impact products. **Figure 5.6** therefore shows a simplified version of the impact-chain.

- **IPCC socio-economic scenarios/shared socio-economic pathways (SSPs):** SSPs are the structured global development trends that guide climate change decisions and related research from the global to regional level. Their use at the sub-national level, however, has yet to be fully established. The advantage of SSPs is that they provide a unified approach for adaptation and mitigation. Though SSPs have been criticized for leaving out future vulnerability considerations, they can still provide a basis for projecting future vulnerabilities through inclusion of specific qualitative interpretations for local contexts. There is a body of work on how to use these scenarios for demographic, economic, natural resource use, governance and policy, and cultural aspects that can be applied at the river basin level.
- **Expert opinion and clarification:** Depending on the engaged experts, this guidance can be less reliable and can often lead to vague conclusions, leading to unverifiable results. Hence, choosing the right experts plays a key role in obtaining reliable results. Judgement for missing values at a limited scale can still, however, be robustly employed if the experts have sufficient expertise and contextual experience.

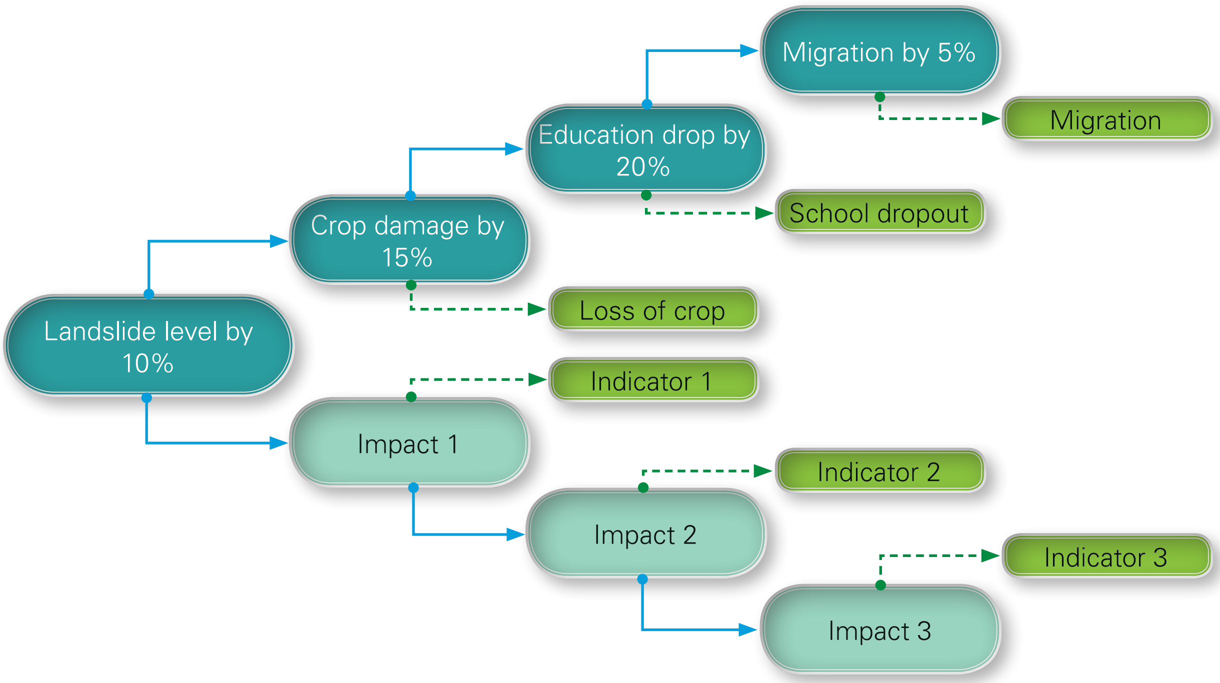


Figure 5.6 Impact-chain approach for identification of scenario-based future vulnerability indicators

- **Adjustment factors:** These factors can be applied to identical socio-economic contexts and can be employed with valid justifications. They can be acquired from current published vulnerability assessment literature. This approach, however, is challenging as it depends on the availability of values for similar contexts elsewhere.

Landslide vulnerability assessment results interpretation

Final sensitivity and capacity values will range between 0 and 1 (Y axis in **Figure 5.7**). Since there are no known measures to equate the amount of sensitivity that will be fully neutralized by a specific amount of capacity, these two values should be read independently. Therefore, a household with a full capacity of 1 may still undergo damages (as represented by its sensitivity value). This household will, however, be able to recover faster due to its higher capacity value.

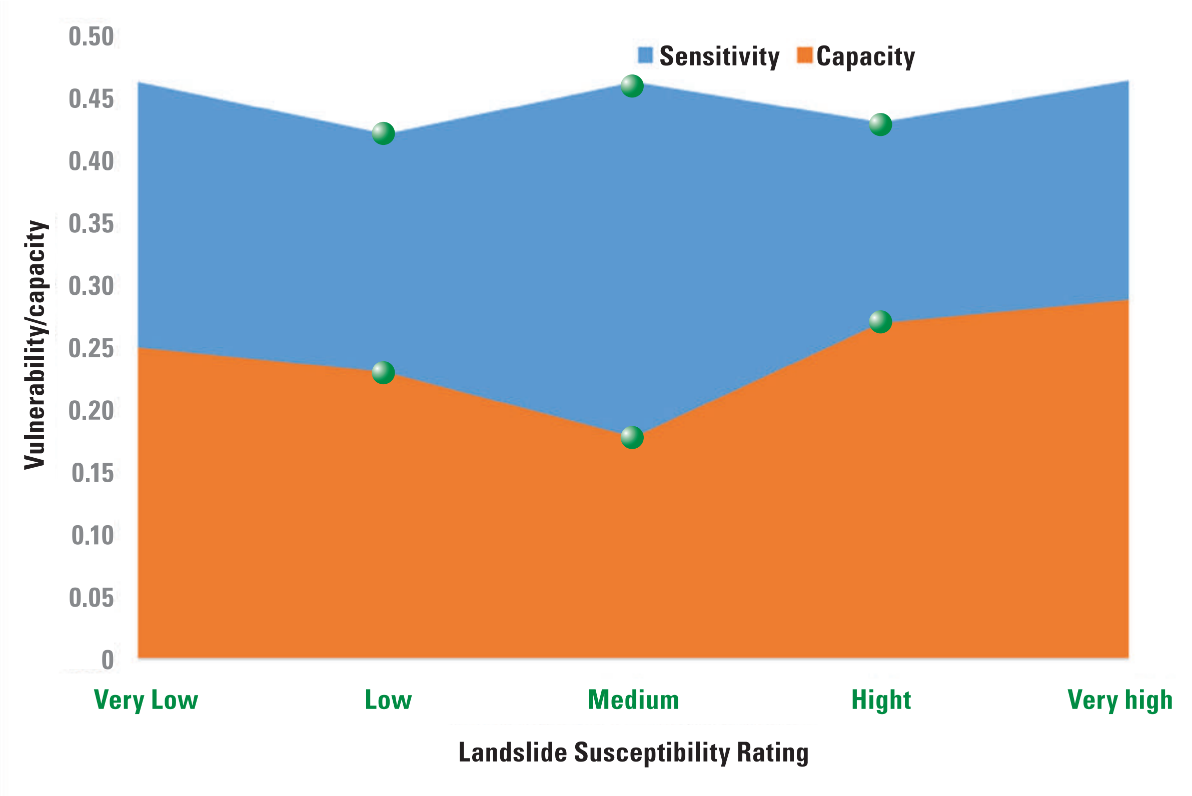


Figure 5.7 Vulnerability and capacity values for different landslide susceptibility classification areas

Photo: Taunggyi - RBP Site, ASEAN DRR-CCA

6 LANDSLIDE RISK MAPPING

Landslide risk assessment is a complex task that requires multi-disciplinary expertise (**Figure 6.1**). The risk assessment process is based on a review of both hazard technical features, such as location, intensity, and frequency/probability, as well as a vulnerability and exposure physical, social, economic and environmental dimensions analysis that recognizes risk coping capacities. UNDRR defines risk in short as "the probability of losses".

Figure 6.1 Multi-disciplinary expertise requirements for a scientific risk assessment approach

Risk can be defined conceptually using the following basic equations:

Risk = Hazard * Vulnerability * Amount of element at-risk (or "exposure")	**(1)**
Risk = Hazard * Amount of element at-risk (or "exposure") * Vulnerability / Capacity	**(2)**

These equations are not only conceptual: they can be calculated using GIS spatial data to quantify risk, with a focus on (direct) physical, population and economic losses. The equations can be applied according to risk assessment purpose.

A disaster occurs when a hazard threat (landslide) is realized and impacts a vulnerable society, including population, critical facilities, and infrastructure such as roads, buildings and other assets.
Hazard risks can be presented in reports, guidelines, etc. that include graphs, tables and maps that illustrate quantitative (monetary loss) or qualitative risk level. Risk attributes, including recommended action levels that demonstrate risk prioritization among multiple hazards, are also included in these examples. **Figure 6.2** provides an example, depicting a color scheme for defining risk levels and corresponding actions

The risks defined in these guidelines are intended for use in the disaster risk management policy context. Risk assessment in these guidelines is used to identify people, buildings, roads and agricultural areas at-risk, the resulting impact in risk reduction, and better management of potential disaster impacts. The risk analysis results will be useful for disaster risk reduction management and resource allocation, as well as coordinated preparedness and mitigation actions. Analysis results can serve as a foundation for designing disaster risk reduction and management strategy and initiative priorities for the government and other relevant organizations.

Color	Risk Level	Recommended Action Level
	Very high risk	Urgent action - Very high risk condition with highest priority for reduction and contingency planning
	High risk	Immediate action - High risk condition with high priority for reduction & contingency planning
	Moderate	Prompt action - Moderate to high risk condition with risk addressed by reduction & contingency planning
	Low	Planned action - Risk condition sufficiently high to give consideration for further reduction & contingency planning
	Very low	Advisory in nature - Law Risk
	No risk	Advisory in nature - No Risk

Figure 6.2 Risk and recommended action level color scheme

6.1. Landslide risk zoning map preparation

Figure 6.3 illustrates a landslide risk assessment workflow that has integrated climate change scenarios. In the workflow, outputs obtained from landslide susceptibility mapping (with and without climate change) are integrated with exposure (risk element), vulnerability and damage. Landslide risk zoning requires identification of risk elements.

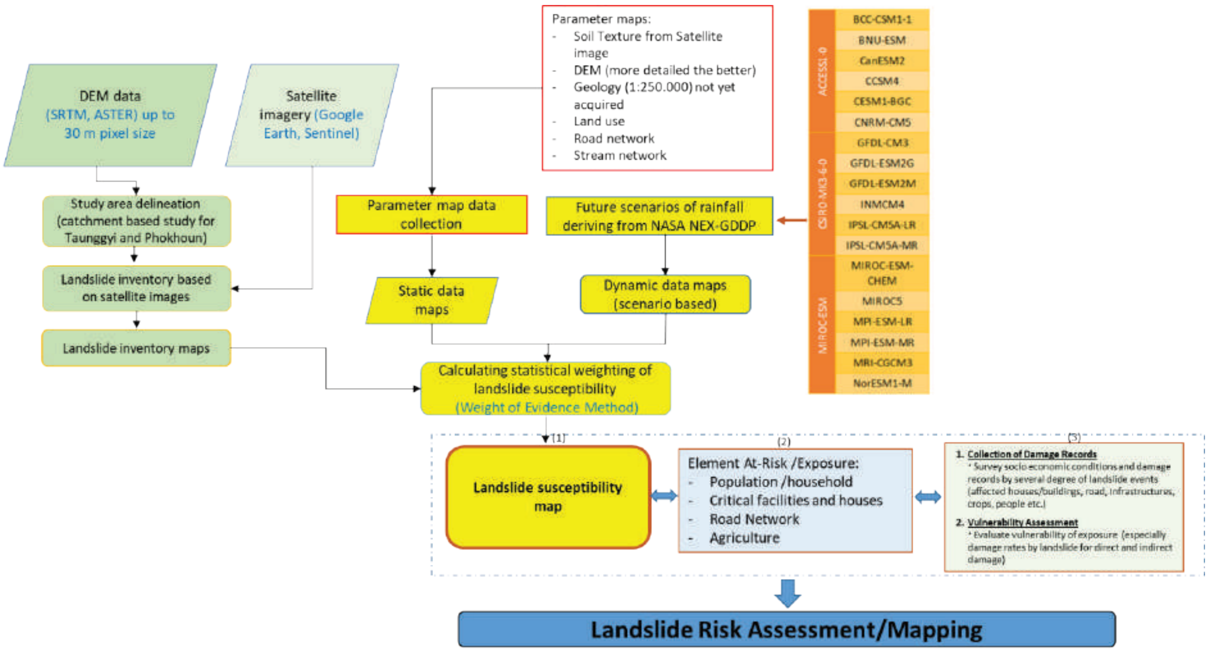
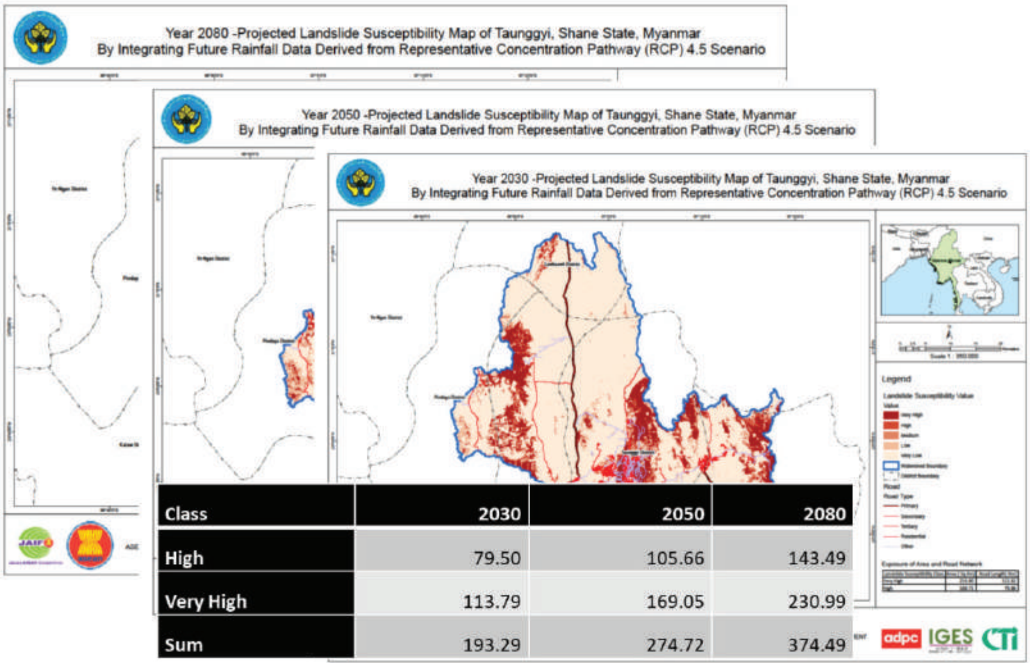


Figure 6.3 Landslide risk assessment workflow with climate change scenario incorporation

Elements at-risk are defined as a population, properties, critical facilities, including public services such as road networks, or any other defined values exposed to hazard in a given area. They are also referred to as assets. Elements at-risk have spatial and non-spatial characteristics. They may include impacts such as reduced economic activity resulting from a landslide, due to, for example, loss of a road or a blocked or damaged road. The characterization of the element at-risk (such as number of buildings, number of people, road length, economic value) also defines how it is presented. Element at risk exposure and vulnerability is defined by its relationship to landslide hazard and risk susceptibility. The spatial interaction between the elements at-risk and the landslide hazard footprints are depicted in GIS by a simple map overlay of the landslide susceptibility map with the elements at-risk map. When the risk equation is calculated using GIS, element at risk exposure is determined through this map overlay technique.

Vulnerabilities can be categorized as physical, social, economic and environmental. For example, community and household vulnerability can be based on a number of criteria, such as age, gender, source of income, etc. that are analyzed using equation 2 as described in Chapter six. According to the equation, vulnerability is evaluated as the interaction between landslide hazard or susceptibility intensity and the type of element at-risk. A vulnerability assessment can be divided into quantitative and qualitative elements. A quantitative vulnerability assessment includes sensitivity factors that can be readily assessed quantitatively in economic terms or physical terms such as crop loss per hectare ton. These factors can be determined using loss and damage data collected by the local government in the immediate disaster aftermath, or through interviews and data collection surveys in the affected communities.

A sample of risk analysis results for road network and vulnerable households (collected from a household survey) exposed to high and very high areas prone to landslide occurrence can be seen in **Figures 6.4 and 6.5**.



Class	2030	2050	2080
High	79.50	105.66	143.49
Very High	113.79	169.05	230.99
Sum	193.29	274.72	374.49

Figure 6.4 Sample of risk analysis results for a road exposed to a landslide hazard

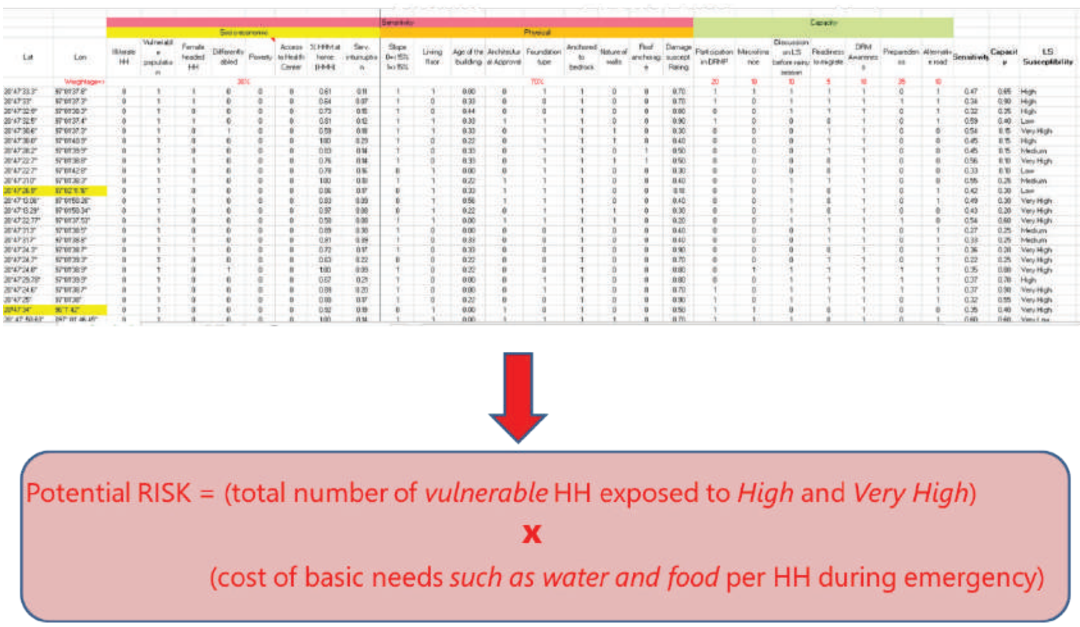
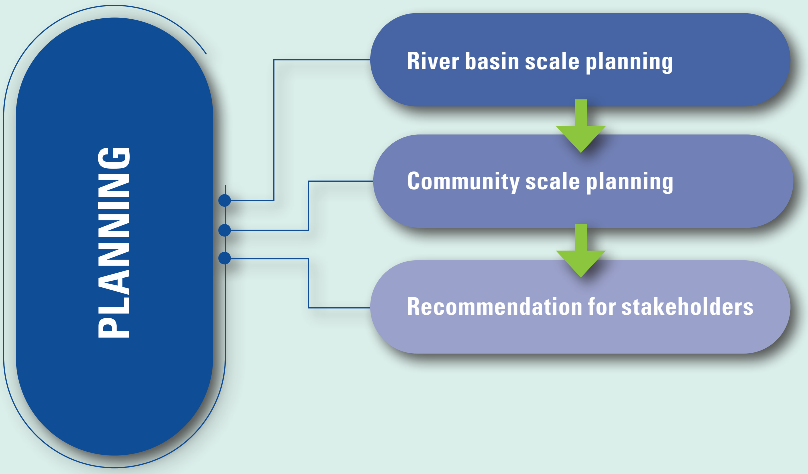


Figure 6.5 Sample of risk analysis results for vulnerable households exposed to a landslide hazard

Photo: Taunggyi - RBP Site, ASEAN DRR-CCA

7 LANDSLIDE RISK ASSESSMENT FOR DISASTER RISK REDUCTION PLANNING



PART III: PLANNING

The next step after risk map development is to use the map for landslide risk mitigation and prevention planning. Risk map analysis results are valuable for developing a basic landslide risk reduction and planning strategy for the target areas at both the basin-wide and community level. Analysis results will be used to determine planning scale, design level and measure type (structural or non-structural).

The following section will explain planning at both a basin-wide, sector based (for example, the road sector) and community specific level, using an approach that accounts for the needs and capacity differences at various governance levels.

The different priority sector outcomes determine the scope of basin-wide DRR planning. Key disaster risk reduction planning stakeholders should determine the priority sector type for the river basin area under assessment.

The sector level risk assessment outcome will be utilized to develop the sector-based landslide risk management strategy, that is usually is comprised of:

- A respective sector long-term vision, goal or overall aim.
- An action plan designed to reduce sector level landslide risk.
- A plan implementation strategy that includes expected duration, an approach for enhancing capacity (human resources, hardware and software, etc.), direction for efficient and effective resource use, and a plan for overcoming policy related challenges.

The assessment plan should project landslide disaster response potential through measures and activities to increase capacities and reduce vulnerabilities. The measures in turn should reduce landslide disaster risk in the focal river basin area. The planning exercise will further help in developing strategies to address inadequacies (such as lack of resources and capacity) and ways to overcome policy related constraints.

Project indicative vision for the road sector
A safer and resilient road network within the taunggyi district

Sector level landslide DRR strategy development starts with a session on **sector level visioning**. This can be done through a facilitated discussion attended by sector level authorities and all other stakeholders. This group should discuss the ideal conditions in which the sector is resilient from landslide risk. Sector level objectives and priorities should be discussed in negotiations for vision statement development and completion. This expression of intent can be presented as a statement, slogan or drawing, or even in the form of a poem or song.

Objectives/priorities
• Minimize disruptions to road transportation system due to landslide occurrence
• Provide ew and reduce the landslide related accidents involving road users and those who are living adjacent to major roads
• Predict and take actions in advance to mitigate the landslide disaster risk within the road network in future

The vision statement will represent the sector's ultimate landslide DRR goal (what they want to achieve) for landslide risk resilience, realized through the risk assessment process.

The stakeholder group may also determine sector priorities and strategy objectives achievement. A sector risk level (hazard susceptibility, exposure and vulnerabilities) that considers all associated risk elements should also be considered, as well as capacity development needs for strategy implementation.

7.1 River basin level landslide risk action plan steps

The landslide susceptibility map, when overlaid with a feature map containing all risk sector elements (population, housing, critical facilities, infrastructure, lifelines, etc.), should provide an indication of elements located in areas with a different degree of landslide susceptibility (such as very high, high, medium, low). The risk level can be defined through the exposure elements degree of vulnerability.

7.2 Selecting measures to reduce or modify landslide risk

While selecting measures to reduce or modify risk, the DRR sector level planning stakeholders should particularly focus on measures and actions that can be implemented considering the policy environment, available human resources capacity, duration of the planning cycle, etc. The planning process should include strategies that address deficiencies, such as providing additional resources, enhancing capacity, and actions to overcome policy related constraints.

Options to consider when addressing landslide risk include the following.

- Accept the risk, which is often possible when it is defined as 'low' or 'moderate'.
- Avoid the risk, which usually requires either abandonment or modification of the proposed new development.
- Reduce landslide occurrence frequency, which generally involves stabilization measures such as groundwater drainage, slope modification to control contributing factors, etc.
- Reduce the consequences, which generally involves relocation of the vulnerable settlement and/or infrastructure to a more favorable location.
- Transfer the risk, which generally requires another party to share or bear it.

Future landslide risk reduction scheme design should consider the following measures.

- Safer risk-based land use planning and resettlement (for reducing exposure through resettlement or relocation of vulnerable elements).
- Living with landslide risk.
- Risk transfer: Transfer of the risk implications from one party (individual or an organization) to a second party (for example, insurance).

The flow diagram in **Figure 7.1** provides a sample landslide DRR planning framework or design scheme.

Examples and explanation of the above three scheme design measures and their sub-components are presented in the **Table 4.1**.

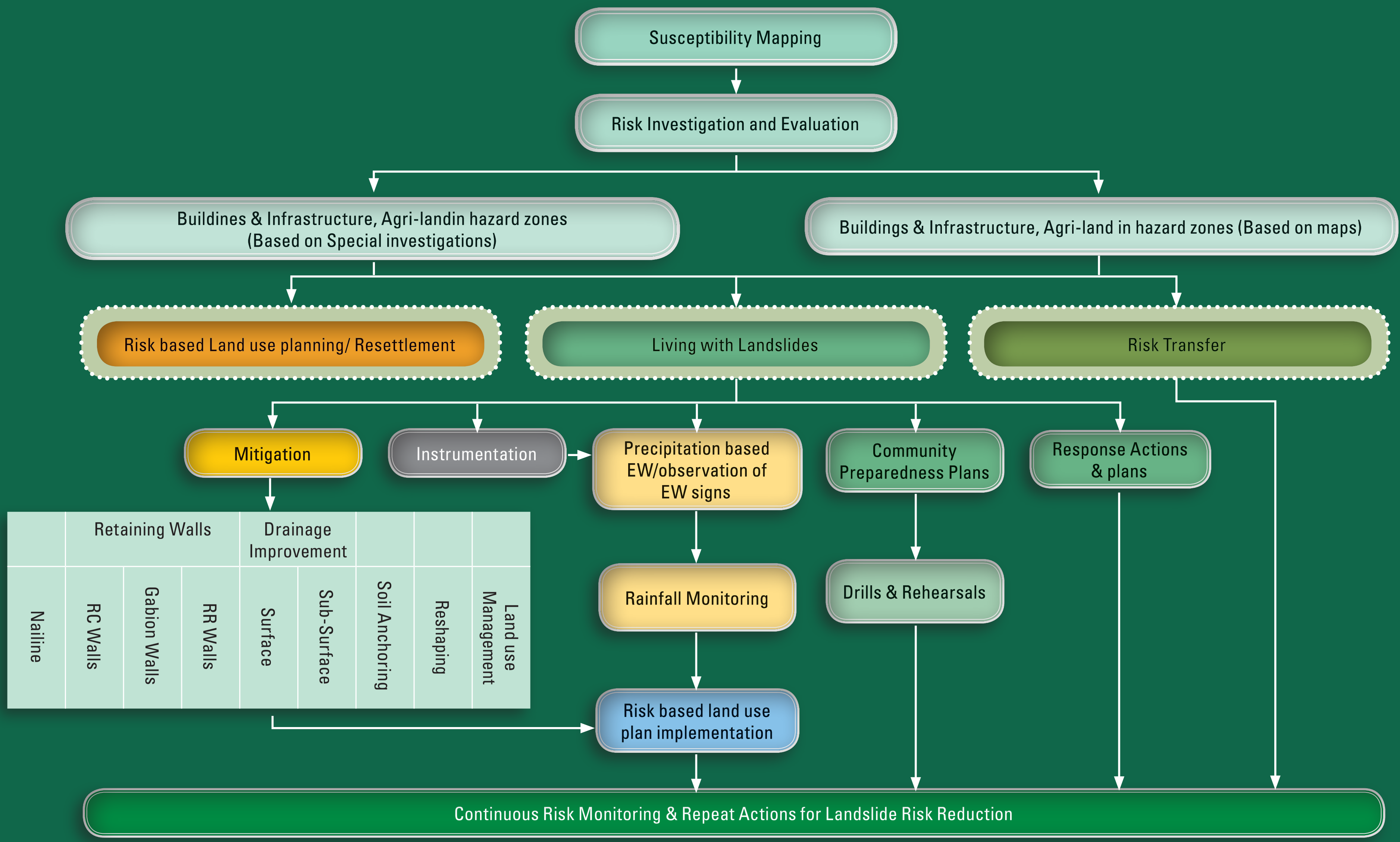


Figure 7.1 A landslide risk management framework.

Table 4.1 Landslide risk reduction measures general classification (source: adapted from UNISDR Report on the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction, December 2016).

Preparedness	Preparedness is defined as the knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, likely, imminent or current disaster impacts. Preparedness actions, carried out within the landslide disaster risk management context, aim to build needed capacities to efficiently manage landslide related emergencies and orderly transition from response to sustained recovery. Preparedness should be based on a sound disaster risks analysis and good early warning system linkages. It includes activities such as contingency planning, equipment and supply stockpiling, development of arrangements for coordination, public information for evacuation, and associated training and field exercises. These activities must be supported by formal institutional, legal and budgetary capacities.
Mitigation	Mitigation is defined as activities implemented with the aim of lessening or minimizing the adverse impacts of hazardous events. Adverse natural hazard impacts, including landslides, often cannot be fully prevented, but their severity or scale can be substantially lessened through various measures and strategies. These mitigation measures can be either structural or non-structural. **Structural measures** are defined as any physical construction to reduce or avoid hazard impacts, or the application of engineering techniques or technology to promote hazard resistance and resilience. Common landslide disaster risk reduction structural measures include retaining structure engineering for slope stabilization, soil or rock formation improvement through cement grouting, rock bolting, soil nailing, surface drainage improvements, sub-surface drainage installation, etc. **Non-structural measures** are defined as those that use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, and training and education. Common landslide disaster risk reduction non -structural measures include building codes, enhanced land-use planning regulations, resettlement programs, etc.
Prevention	Prevention is defined as activities and measures to avoid existing or new disaster risks. The landslide disaster prevention concept conveys the intention to avoid all potential hazardous event adverse impacts. Prevention aims to reduce vulnerability and exposure to a lower acceptable level of landslide disaster risk. Examples include: land -use regulations that do not permit settlements in high-risk zones and designing buildings or road networks to ensure they continue to function after a disaster event. Prevention measures can also be taken during or after a landslide event to curtail secondary hazards or their consequences.
Avoidance	Avoidance is defined as the protection of elements to exposure during a potential landslide event. Examples include: land-use planning for greater safety and/or relocation of existing facilities and communities to safer areas, installation of warning instruments in potential landslide locations, monitoring landslide area changes, and alarm systems for potentially dangerous conditions.

Risk transfer	Risk transfer is defined as the process of formally or informally shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs in exchange for providing ongoing or compensatory social or financial aid to that party. Insurance is a well -known form of risk transfer, where risk coverage is obtained from an insurer in exchange for ongoing premiums paid to that insurer. Risk transfer can occur informally within family and community networks wherein there are reciprocal expectations of mutual aid by means of gifts or credit, as well as formally, wherein governments, insurers, multilateral banks and other large risk-bearing entities establish mechanisms to help cope with losses from major events. These mechanisms include insurance and reinsurance contracts, catastrophe bonds, contingent credit facilities and reserve funds. Costs are covered by premiums, investor contributions, interest rates and past savings.

7.2.1. Living with risk

The general approach for living with landslide risk is to create a safer environment through preparedness and mitigation measures, as well as enhancing response capacity for landslide events.
Landslide early warning response
Response is generally defined as the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet basic subsistence needs.

A response is necessary -

- When at risk communities receive early warning about a possible reach or exceedance of thresholds set for a landslide event, or,
- after observing landslide initiation signs. These scenarios may both happen at the same time.

Early warning is a set of preparedness activities, systems and processes that enables individuals, communities, governments, businesses and others to take timely action for disaster risk reduction in advance of hazardous events. It can be defined as an integrated system of hazard monitoring, forecasting and prediction and communication and disaster risk assessment.

An early warning system should be "end-to-end" and people-centered, meaning that the system is able to integrate interventions from the trigger moment up to interventions that aim to extend assistance to people so that they can interpret early warning messages and react to them efficiently. The system should be capable of covering all community needs without leaving anyone unattended.

These four interrelated components (hazard monitoring & forecasting, prediction, communication and response) require multiple-level coordination within and across sectors for the system to be effective, as well as to provide a feedback mechanism for continuous improvement. Lack of coordination or the failure of one component could lead to failure of the whole system. The landslide trigger threshold is based on a specific recorded rainfall or precipitation level.

Established landslide trigger precipitation thresholds are area specific and based on measures for a specific duration, for example rainfall accumulated during a 24-hour period, or during three days or seven days. The warning has three stages: alerting the community, preparing for evacuation to a safer area, and executing the evacuation to a pre-identified safer location. The warning remains valid until the community receives a message from authorities that the foreseeable danger has passed and members can return to their home location.

An example of rainfall thresholds used for landslide early warning is provided below.

"Alert" - **75 mm** rainfall in 24 hours: Increase vigilance and observe appearance of any symptoms of slope destabilization on critical slopes.

"Get ready for evacuation" - **100 mm** rainfall in 24 hours. Be ready to move to a safer location.

"Evacuation" - **200 mm** rainfall in 24 hours. Evacuate to safer places.

Buildings, roads, infrastructure facilities and the ground often show landslide early warning symptoms. Community members should stay vigilant during high rainfall events in order to identify these symptoms and inform authorities. **Table 4.2** provides early warning symptom examples.

Table 4.2 Landslide early warning symptom examples and response indicators

Example	Response indicator
An unusual number of cracks on building walls, and their rapid expansion	 (Remark: get advice on further actions from a technically competent authority)
Appearance of cracks on the ground	

Example	Response indicator
Cracks on the building floor, and their rapid expansion	
Sudden appearance of cracks on the ground or road surfaces, and/or ground slumping	
Sudden appearance of higher water flow or quantity, appearance of new springs, or disappearance of existing springs	

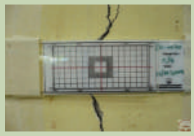
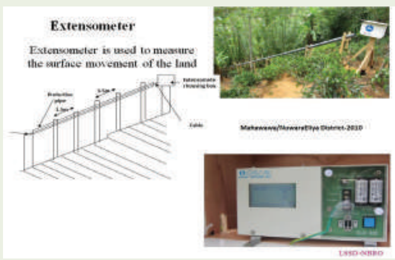
Landslide risk reduction preparedness measures

Landslide risk reduction preparedness is defined as knowledge and capacities developed to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.

Landslide preparedness measures include the actions below.

- Post public information sign boards at landslide and rock fall vulnerable locations.
- Develop alternative road links for critical road sections that are landslide vulnerable.
- Develop community level preparedness plans.
- Identify evacuation areas and prepare evacuation plans.
- Organize community preparedness drills, rehearsals, etc.
- Undertake preparedness training and capacity building activities.
- Provide early warning instrumentation for monitoring slope destabilization, house walls, etc. in known hazard areas and activate a hazard alarm system (see **Table 4.3**).

Table 4.3 Surface movement and wall crack expansion monitoring instruments

Name of instrument	Purpose	Example
House wall surface crack measuring device	A simple surface crack measuring device can be installed on house walls to measure the progressive expansion of cracks.	 
Extensometers	Extensometers are usually installed on vulnerable slopes for slope surface movement monitoring	

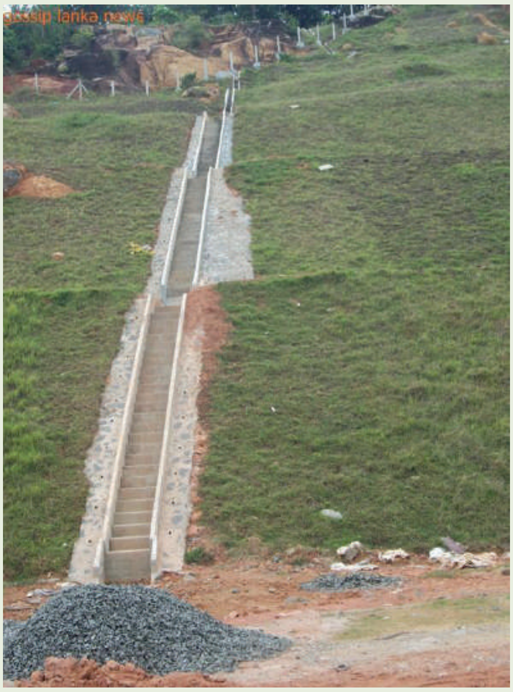
Landslide risk mitigation measures

A general definition of mitigation is the lessening and limiting of a hazard and related disaster impact. Mitigation measures to reduce landslide risk can be:

- **Structural/engineering measures**, such as geo-engineering measures, bio-engineering measures, civil engineering measures, etc.
- **Non-Structural measure**s such as land use planning, resettlement, capacity building, awareness raising, knowledge management, risk transfer mechanisms, etc.

Commonly used landslide risk reduction structural mitigation technologies and options are provided in **Table 4.4.**

Table 4.4 Commonly used landslide risk reduction structural mitigation options and technologies

Purpose	Structural/engineering measures	
Slope protection and stabilization	• Benching • Mechanically stabilized earth • Subsurface drains • Grouted riprap protection walls	
Slope stabilization	• Gabion walls • Soil nailing • Rock anchoring • Geotextile walls • Rock barriers and shelters	
Surface and sub-surface drainage	Surface drainage can reduce subsurface layer water infiltration and saturation A ground water table at risk of rising to unsafe levels can be kept in check with: • Sub-surface drains • Sub-horizontal directional drilling • Drainage wells	 

Purpose	Structural/engineering measures	
Combination of measures	Combination of: • Shotcrete facing soil nailing • Drain berm designed to cascade • Sub-horizontal drains • Gabion wall	 
Slope stabilization in rockfall areas	• Rock barriers • Tunnels • Walls/barrier cuts • Rockfall protective shelters	
Nature based solutions	Bio-engineering (Sloping Agriculture Land Technology – SALT)	
Structural and bio-engineering measure combinations	Surface drainage, benching, gabion walls and other retaining structures, for example.	

Appropriate mitigation measure criteria selection

The most appropriate mitigation measures should be adopted according to the following factors.

- Factors that determine the degree and susceptibility of a hazard, in terms of the type, rate, depth and movement or landslide occurrence probability.
- Factors that affect the quantification and nature of a given hazard, such as the presence of elements at risk vulnerability, in both potentially unstable areas and those that might be affected by the run-out
- Factors that affect mitigation measure feasibility, such as:
    - o Capital and operating cost, including maintenance
    - o Landslide phase and movement rate
    - o Area morphology in relation to resident community, construction worker, general public, etc. accessibility and safety.
    - o Environmental constraints such as impact on the archeological, historical and visual/landscape value of the location
    - o Preexisting structures and infrastructure that might be affected, either directly or indirectly.

Table 4.5 Indicative sector level risk reduction measures (road sector)

Mitigation measure	Preparedness measure	Response measure
• Introduce risk sensitive road infrastructure planning guidelines for high and medium risk areas based on landslide hazard maps. • Develop a design manual for selection and design of engineering measures (civil, geo and bio-engineering for stabilization) for landslide and rock fall vulnerable areas. • Apply appropriate road design and construction practices to landslide vulnerable areas based on susceptibility mapping data. • Develop a rapid identification system for stabilizing priority road sections. • Develop guidelines for safer and more resilient slope extraction practices and filling/reclamation operations. • Introduce instrumentation, techniques and monitoring for accident avoidance in critical landslide vulnerable areas. • Demonstrate cost effective remedial measures, including gabion use and jute geogrid and geotextile, "deep trench drain" and "soil nailing" techniques for landslide stabilization and bio-engineering solutions. • Initiate technical road sector staff and other stakeholder training programs.	• Prepare an inventory and database of road sections vulnerable to landslides and rock falls using landslide susceptibility map data. • Inform the public through sign boards of landslide vulnerable road sections and rock falls. • Provide instrumentation for monitoring rock falls, slope destabilization and alarm system activation to avoid road accidents in known hazard areas. • Develop alternative road links for landslide vulnerable road sections. • Develop road sector preparedness plans with the involvement of planners and other stakeholders, including road users. • Initiate preparedness training and capacity building activities for road sector officials.	• Activate sector level EOC in the district headquarters • Build maintenance units with the required human resources and equipment to locate and clear debris in high risk sections • Build a vigilance team tasked with monitoring road transport difficulties due to landslides caused by high precipitation events. • Develop a rapid road network slope failure system to gather information during high rain periods. • Divert traffic away from problematic areas through policing. • Inform the public on road conditions through temporary sign boards, the media, etc. • Initiate temporary measures to reduce further impacts.

7.2.2. Risk-sensitive land use planning and reducing exposure through vulnerable element resettlement and relocation

Planning for resettlement to safer land is applicable when landslide susceptibility is very low, but other factors need to be considered when identifying suitable land. Studies on safer land for families living in high landslide risk areas should fulfill two specific purposes.

1. Identification of safe resettlement land.
2. Assessment of identified land suitability for the vulnerable family.

A landslide susceptibility map provides hazard categories that are delineated through the hazard assessment. A high landslide probability zone is a result of landslide hazard susceptibility in a specific land category. The other two zone categories – modest landslide hazard and landslide not likely to occur – need further screening for identification of land safe for resettlement.

Potentially safe land should be identified through a desk study covering lower susceptibility areas on the hazard zonation map with satellite and/or Google images using the following criteria.

<u>Closeness to settlements</u>
Vacant land areas that are more than two acres away can be identified using QGIS open source software. The location of settlements, villages, urban centers, etc. that are within close range to the identified vacant land can be obtained through published maps (such as maps published by the Survey Department). The direct distance to such settlements is one of the most important data analysis factors.

<u>Accessibility</u>
Land accessibility, defined as transportation routes located close to the available land, is another important factor to consider. If the land cannot be accessed directly, creating access for vehicular transportation can be considered.

<u>Legal reservation avoidance</u>
Some suitable areas may be reserved for other purposes. These areas should be avoided during the screening process.

<u>Environmental sensitivity</u>
Published land use maps should be used for the environmental sensitivity assessment. All environmentally sensitive areas, including those prone to other types of natural hazards such as floods, tsunamis, etc., should be excluded.

<u>Slope gradient</u>
Slope gradient must be considered during the screening process. Slopes less than 15 percent are considered to be out of excessive slope range. Slopes with a minor gradient are usually preferred in order to avoid additional operational costs such as land preparation, filling, excavations, leveling or building additional retaining structures, rainwater drainage, etc. It is essential to assess slope gradient during field inspections.

Once the land is identified, houses can be constructed only after developing a site layout plan and building access roads and utilities such as electricity, water, etc. Housing construction can be an owner driven program, or the government can distribute houses already constructed by a suitable contractor.

7.2.3. Risk Transfer

The unexpected can still happen even after an acceptable risk level has been reached through the measures listed above. Situations outside the norm can lead to a higher number of landslides, flood events and socio-economic impacts. For example, in July 2005 Mumbai, India had 944 mm of rainfall – the highest recorded in a single-day in India's history. In 2006, flash floods and landslides in the northern part of the Thailand affected 4 provinces and left 87 people dead and 29 missing, with more than 4,000 houses totally or partially damaged.

A risk transfer process that formally or informally shifts the financial burden of particular risks from one party to another can help address the consequences of such unexpected events. A household, community, enterprise or state authority will be able to obtain resources from the other party after a disaster occurs in exchange for compensatory or ongoing social or financial benefits provided to that other party. Insurance is a well -known form of risk transfer, where risk coverage is obtained from an insurer in exchange for ongoing premiums paid to the insurer. Risk transfer can occur informally within a family or community through community managed funds such as Durian Fund in Thailand's Uttaradit Province, where the community can use funds accumulated through donations during durian harvesting season. Community members can access the Durian Fund to get relief during emergencies such as unexpected landslide and flash flood events, etc.

7.3. Landslide risk management action plan and implementation strategy

Sector level landslide risk management actions under response, preparedness and mitigation should be combined for the landslide risk management plan. The plan implementation strategy should include four main aspects: expected duration, implementation resources, capacity assessment, and a policy level analysis.

Implementation duration
Implementation duration, can be assigned to one of the three categories below.

ST-Short term - less than six months
MT-Medium term – six months to three years
LT- Long term – more than three years

Implementation resources
Resource needs for identified action implementation can be assigned to one of the categories below.

AD - Available provisions are currently adequate.
MA - Available provisions are not currently adequate, but can be obtained through annual government budget allocations.
NAD - Need external resources as requirements exceed annual budget allocations.

Implementation capacity
A human resources capacity assessment is essential. It can be assigned to one of the categories below. Human resource needs for external implementation should also be included in the budget.
AD - In-house capacity is adequate.
MA - In-house capacity is not adequate but technical assistance from within the department can be made available.
NAD - Need to request external support.

Policy requirements
Implementation policy can often become a bottleneck. Solutions for overcoming these constraints should also be identified and included in the strategic plan. Policy requirements can be assigned to one of the categories below.

AD - Present policy and institutional arrangement is adequate.
MA - Present policy and institutional arrangement is not adequate, but can be revised through minor changes.
NAD - Present policy and institutional arrangement is not adequate and a new policy and arrangement must be introduced.

An indicative sector-based landslide risk management strategy and plan is provided below in **Table 4.6**. This strategy should be approved by sector level authorities and follow country implementation procedures.

Table 4.6 Indicative sector-based landslide risk management plan and strategy

Phase	Indicative activities	Duration			Resources			Capacity			Policy needs		
		ST	MT	LT	AD	MA	NAD	AD	MA	NAD	AD	MA	NAD
Response	Form a vigilance team in the appropriate department district HQ that monitors high precipitation events.	x			x			x			x		
Preparedness	Prepare an inventory and database of areas (covering each sector) vulnerable to landslides and rock falls using landslide susceptibility map data.	x			x			x			x		

Phase	Indicative activities	Duration			Resources			Capacity			Policy needs		
		ST	MT	LT	AD	MA	NAD	AD	MA	NAD	AD	MA	NAD
Preparedness	Install sign boards at areas vulnerable to landslides and rock falls for informing the public.	x				x		x			x		
Mitigation	Develop a building code or guidelines for appropriate construction in landslide prone areas.		x			x				x			x
Mitigation	Hold demonstrations on cost-effective remedial measures such as gabion and jute geogrid and geotextile use, "deep trench draining", "soil nailing" techniques for landslide stabilization, bio-engineering solutions, etc.			x			x			x			x

7.4. Upscaling sector level landslide DRR plans and their incorporation into the national development planning process

As ASEAN Member States pursue their national development goals, they must consider climate change and disaster risk in every planning cycle and ensure that all new development is adequately protected while also ensuring community, infrastructure and other current development is resilient.

This calls for government commitment to risk-sensitive development policy and planning in key sectors such as infrastructure (roads, power and energy, water supply, etc.), human settlements and housing, health, education, agriculture, industry, etc. Risk-sensitive development may require shifting future building, critical infrastructure and lifeline facility construction into safe areas and a mandate that sectors such as infrastructure, roads, housing, etc. factor disaster risk into their projects. At the same time, national plans should include better disaster response actions and preparedness capacity instruction for communities at risk. National, sub-national and/or local or sector level development policy and planning should adequately cover all of these disaster risk reduction and climate change adaptation aspects.

All DRR plans, including sector or community level landslide DRR plans, should be incorporated into planning processes such as national (short, medium or long-term) development plans, sectoral development policy, urban development, national budgeting and resource allocation policy, land-use planning and spatial development policy, etc. These planning processes guide development, and by integrating climate change adaptation and disaster risk management into these instruments, ASEAN governments can help ensure resilient development. For example, in Lao PDR, a sector level landslide DRR planning exercise should be incorporated into the government's 9th Five-year National Socio-economic Development Plan, 2021-2025. In doing so, Lao PDR can secure resource allocation for implementing identified landslide DRR actions, build capacity, and create an enabling policy environment for implementation.

7.5. Community based participatory landslide risk management strategy

A community-based landslide risk assessment is a process to identify a community's landslide risk and enhance knowledge to stimulate appropriate action to create a safer environment. The assessment should target the most vulnerable and give priority to communities living in high landslide susceptible areas. The process includes a hazard assessment, a vulnerability/capacity assessment, action planning, risk reduction implementation prioritization, and a resources availability analysis. The ideal community based participatory landslide risk management strategy (CBPLRMS) process will be led by local authorities and include the involvement of identified high-risk communities, community leaders and facilitators (project team members).

Below are the proposed CBPLRMS development process steps.

Community based landslide risk reduction planning and management

The most vulnerable communities living in areas with high landslide risk must be identified. This can be done using the landslide risk assessment results. A community-based landslide risk reduction and management (CBLRRM) plan targeting the identified communities is the next step. The plan includes measures and activities to reduce landslide susceptibility and community vulnerabilities, as well as to increase capacities, that will ultimately result in landslide disaster risk reduction. The CBLRRM exercise will produce strategies to address identified risks, for example, identifying safer shelter, responding to emergency warnings, increasing safety through mitigation measures, determining needed resources, and establishing community member and other stakeholder roles and responsibilities.

Participatory disaster risk management planning

Participatory disaster risk management planning is a process wherein all parties propose concrete risk management activities based on the following.

- Community vision.
- The acceptable risk level.
- Whether identified risk can be prevented, mitigated or accepted.
- Capacities that can be upgraded and resources that can be generated within and/or outside the community.

The following components in the process should be considered.

- What the community wants to achieve. (goal/vision)
- Why does the community want to get there? (purpose)
- How to get there? (strategy)
- Does the community have the competence to get there? (capacity assessment)
- What does the community need to get there? (resources assessment)

A community session on visioning based on the risk assessment exercise results is essential. This visioning should take the form of where the community wants to be in future in terms of reducing landslide impacts. Community members, local authorities and all other stakeholders discuss their vision, or dream (its purpose and priorities), and negotiate and agree on what they want to achieve in the landslide risk reduction planning process.

Converting the vision into action

In converting the vision into action, it is essential to understand the risk environment, identify risk reduction measures, and develop a risk management strategy. Identified activities in this process can be implemented through:

- A timeframe
- Using required resources
- The implementing institution
- Assigning roles and responsibilities
- A plan review and revision process

Discussions during various steps in the DRR strategy development exercise should focus not only on risk environment and risk reduction activities, but also an approach for minimizing hindering factors. Exercise facilitators can adapt the following steps in order to develop trust and promote good exercise understanding among participating community members.

Step 1: Conduct feature mapping

Gaining community trust is the key for success in facilitating effective participation in disaster risk planning and strategizing. Feature mapping helps develop this trust and community confidence. If community members have trust in the outside facilitators with which they are collaborating, they will not be reluctant to share information related to the risk environment and the difficulties, issues, problems, constraints, etc. in building landslide risk resilience. Below are mapping steps that will help ensure fruitful collaboration.

Figure 7.2. Community level landslide risk map

- Start with a transect walk across the selected community.
- Hold a discussion between facilitators, DRR volunteers and the community to prepare a map showing exposed and vulnerable elements and landslide susceptibility and risk.
- Develop fitting symbols for houses, vulnerable slopes, vulnerable population groups, etc.
- Use different symbols to mark the following on the exposure map.
    - o Vulnerable houses, using criteria such as proximity to vulnerable slopes, construction type, resilience features, etc.
    - o Vulnerable slope areas, using criteria such as previous landslides, slope failures, cuttings, ground tension cracks, etc.
    - o Houses where vulnerable populations, such as elderly people, pregnant women, small children, etc. live.
    - o Vulnerable infrastructure, such as roads, water supply, electricity supply, etc.
    - o Critical facilities, such as schools, hospitals, food storage, government buildings, etc.
    - o Buildings that can be used as evacuation centers, for example temples, community centers, etc.

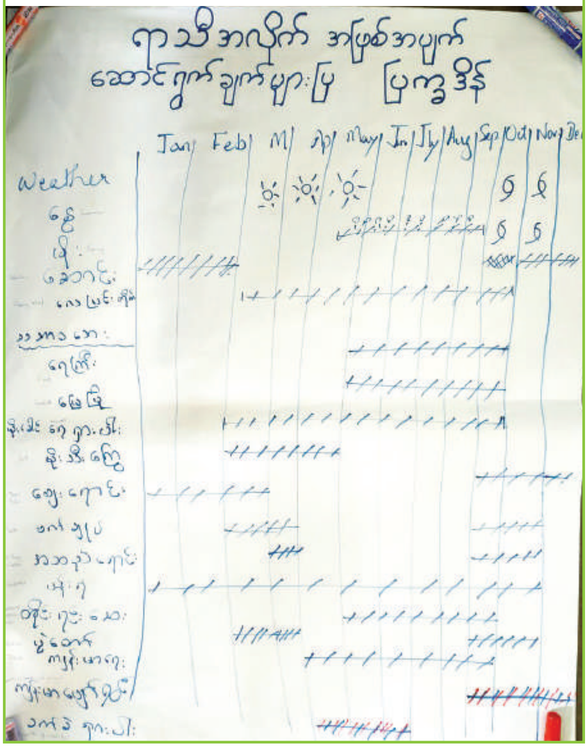
Step 2: Prepare a seasonal calendar

The purpose of a seasonal calendar is to identify problems with managing various seasons and issues, constraints and difficulties that increase community level vulnerabilities. The objective of this exercise is to collect information through a participatory approach and generate constructive dialogue to understand problems associated with community vulnerability.

Record the following for the calendar.

- When the monsoon season will start and end.
- When the community experiences and records different types of impacts due to hazards.
- Other issues responsible for increasing vulnerabilities, and when they occur.
- Community resources, and when they are available.
- The likelihood of contributions, and when those contributions are available.

Figure 7.3. Seasonal calendar



Step 3: Conduct community resource mapping

Community resource mapping determines which risk reduction activities are at hand – those that can be undertaken with available resources (including existing and accessible resources). The objectives of community resource mapping are:

- Identify community resources such as labor force, tools and equipment, working animals, food storage, etc.
- Identify *when* community resources are available, in what quantity, seasonal resource variations, etc.
- Determine the likelihood of damages and losses to community resources and when they might be damaged.

Figure 7.4. Community resource mapping

Below is a listing of community resource examples.

Human: Masons, carpenters, construction workers, health workers, teachers
Materials and supplies: First aid kits, public address systems, cement blocks, rock, timber, animals

Equipment: Communications and transportation, including megaphones, two-way radios, telephones, bicycles, trucks, tractors, etc.

Facilities: Community centers, warehouses, shops and grocery stores, evacuation centers or shelters, roads and bridges

Knowledge: Community knowledge, rural technology, skills that community members possess
Organizational leadership: Women's societies, farmer societies

Funds: Community funds (for example, the Durian Fund, Avocado Fund, etc.), community contributions, such as those for a revolving fund to help during emergency situations.

An inventory of community resources and their availability should be completed. Consider the following questions when preparing the inventory.

- What type of resources (infrastructure, skilled and unskilled labor, community funds, committees and institutions) are needed for landslide risk reduction implementation?
- What type of resources are readily available within the community?
- When are such resources available?
- What type of resources and technical assistance can be supplied by outside parties?

Step 4: Prepare a community action plan

A community action plan provides short and long-term measures for reducing existing risk, minimizing factors that can create future risk, improving capacities, reducing vulnerabilities, etc. The plan expands on specific short and long-term recommendations that are developed through community consultations and review and analysis of the current and future risk environment. It is developed with the expectation that the identified activities can be implemented within a phased time frame. The time frame decision for action plan implementation is based on the recognition that certain existing gaps, limitations and constraints in terms of resources, manpower, technical capacity, etc. can be overcome in a relatively short period of time while others will take longer.

The following examples can serve as the sample risk management actions.

- Activities to strengthen capacities and decrease community vulnerabilities.
- Activities that will help reduce existing risk, such as emergency response, preparedness, risk mitigation, resettlement, risk financing, etc.
- Activities that will help reduce future risk such as policy mainstreaming, new policies and laws, guidelines, improvement in institutional structure and mandatory provisions, incentives (such as tax benefits for land and housing, reductions in duties, tolls and tariffs for local government services, etc.), disincentives (introduction of higher taxes, additional duties, toll charges for local government services), etc.
- Capacity building (including reinforcing existing coping strategies).
- Knowledge management and public awareness.

Step 5: Prioritization criteria

Identified actions cannot all be implemented overnight. Therefore, they should be prioritized using the following criteria.

- Focus on the most critical risk elements and consider potential damage and losses, risk element importance to the community, etc.
- Resource (human, materials, equipment, financial, skills, etc.) availability.
- Number of beneficiaries, and scale of selected action impact and benefit.
- Implementation of a risk reduction measure timeframe (considering factors such as seasonality, routine community cultural activities, etc.)

Step 6: Conduct a stakeholder analysis
A stakeholder analysis is the identification and analysis of key persons, groups and organizations that will have some stake in the risk reduction process. These stakeholders can be categorized as below.

- Those that may be involved in, or impacted (positively or negatively) by, risk reduction activities
- Those that can support and contribute to the community plan
- Those that may oppose the community plan

Why is a stakeholder analysis carried out?
The stakeholder analysis can be carried out using a social and organizational analysis with a matrix and participatory tools such as a Venn Diagram. The analysis is important for the following reasons.

- To list the necessary actions, interventions or activities that will involve identified stakeholders and address their issues and concerns.
- To widen the risk management strategy support base, sustain and increase involvement and participation, and inform and engage strategy opponents.
- To ensure positive stakeholder contributions in implementation of the community plan.

Stakeholders are varied and some may not have participated in the action plan preparation. Hence, it is beneficial to obtain the support of those that were absent during the action plan preparation to ensure successful implementation and get their viewpoints in regards to proposed community action, their possible role and contribution, etc. It is useful to know if stakeholder expectations are different from those of the local community. Support from influential stakeholders for all planned interventions will ensure success. The stakeholder analysis can be carried out systematically through use of the matrix provided below in **Table 4.7**

Table 4.7 Social and organizational analysis matrix

Supporters	Opponents	Current status of relationship with the community	Stakeholder interest and expectations	Power and influence exercised	Role in the community plan implementation	Necessary actions to gain support, or neutralize

Step 7: Conduct a resource analysis
A resource analysis provides the fuel for the three main steps of a community-based risk strategy (feature mapping, community action plan preparation, stakeholder analysis) as described above. It is carried out to determine risk reduction activities immediately at hand – those that can be undertaken with available resources (existing and accessible). It will provide information about needed external resources for remaining activities.

Table 4.8 Resource analysis matrix

Resources needed for DRR actions	Existing resources and their location, ownership and accessibility for use	Resources not accessible for use. What makes them inaccessible?	Actions or interventions needed to make existing resources accessible. How long will it take to make these resources available?	Actions or interventions needed to generate additional resources to meet the resource gap. How long will it take to make these resources available?

Strategy implementation

After completing the community level risk management plan it is essential to develop strategy for implementation. An organizational structure for intervention implementation should be included in the strategy. The structure should facilitate achievement of strategic goals and objectives. Implementing the community level action plan through a committee structure is essential. An organizational structure can be comprised of various committees. This member committees taking part in the organizational structure, can be given specific role/s, allocated with different tasks and responsibilities for clarity, maximum efficiency and improvement of the quality expected during execution of roles. The implementation strategy should integrate both the organizational structure and performance monitoring system.The same strategy should be utilized to motivate the members of the respective committees to ensure timely completion of given responsibilities and effectiveness. The member of committees and membership of individual committees that should be included in the implementation strategy can be determined by the community members depending on the roles assigned to each committee.

Below is an example of a possible committee list.

- Disaster Mitigation Committee
- Early Warning Committee
- Evacuation Committee
- Search and Rescue Committee
- Evacuation Center Management Committee
    - Health Committee
    - Food Committee
- Networking and Public Information Committee
- Training and Education Committee

Community landslide disaster risk management plan final reporting format

Once the community landslide disaster management plan is developed, community members should make arrangements to develop a report and present it to government authorities for obtaining approval and allocating necessary resources for plan implementation. In some countries there is a defined report format that should be followed. A sample reporting format is provided below for those that do not have a prescribed format.

1. Provide village name and short description (number of houses, population, past landslide impacts, etc.).
2. Identify all 'elements at risk' (physical, economic, material, social, cultural, institutional).
3. Examine your list and prioritize those elements most at risk. Prioritization criteria could be those elements projected to suffer the most damage or those most critical for community functioning, or other considerations based on experience in how the community perceives these risks. <u>Underline the prioritized elements at risk.</u>
4. Suggest measures that would reduce elements at risk vulnerability.
5. Write brief notes to describe the potential impact of the risk reduction measures on various risk elements.
6. Provide the stakeholder analysis.
7. Provide a list of resources needed for identified actions. Prioritize actions.
8. Suggest an implementation strategy that includes roles and responsibilities.
9. Suggest risk management plan implementation improvements to ensure safety and resilience (based on present community capacity, resource availability, policy and practice).
10. Complete a monitoring and evaluation agenda for risk management plan review and revision.
11. Secure necessary authority approval.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8 CONCLUSIONS AND WAY FORWARD

The Sendai Framework on Disaster Risk Reduction challenges all stakeholders to improve disaster risk knowledge through focus on establishing and increasing capacity to manage their country's disaster risk and disaster risk assessments. A Landslide Risk Assessment increases disaster risk knowledge and capacity, and provides the foundation for developing a sound national level landslide risk management strategy and actions. The following conclusions and way forward provide recommendations for consideration by relevant authorities, including the National Disaster Management Organization (NDMO) and all stakeholders, to enhance national landslide risk assessment capacity and utilize assessment results to build resilient communities in the future.

8.1. Streamline baseline information collection, data sharing and database maintenance

As these guidelines show, a landslide risk assessment is a process-oriented intervention and has to be carried out in several steps. The first step is landslide susceptibility mapping and hazard zoning. This provides information on different hazard levels in various locations within the hazard prone area. An exposure assessment is the next step. This assessment helps compile an inventory of assets, their characteristics and level of exposure to landslide impacts. Vulnerability is usually defined as the state of being prone to, or potential susceptibility to, losses and damages to various elements located within a specific area. Vulnerability assessment also provides parameters for assessing the physical, social and economic dimensions of prescribed vulnerabilities. It should therefore also determine a community's capacity level, or its ability to cope with or rebound from a given hazard event.

Previous chapters describe in detail the baseline data needed for the risk assessment components. These main components are: hazard assessment (landslide inventory data, landslide attribute data, precipitation data, etc.), exposure assessment (buildings, critical facilities, infrastructure, lifeline facilities, land users, etc.) and vulnerability assessment (physical, social and economic elements). The responsibility for collection of this baseline data lies with a diverse number of national agencies that have official mandates for data collection, data maintenance, data verification, data sharing, etc. These agencies need to be reviewed as their responsibilities and mandates may not necessarily cover data collection to satisfy the needs of the above-mentioned landslide risk assessment components. Therefore, the National Disaster Management Organization (NDMO) is responsible for discussions with the respective agencies and higher authorities (ministries, departments, etc.) so that the risk assessment data collection process can be systematized at the agency level. This will allow the respective agencies to consider essential factors such as scale, frequency, coverage, etc. to suit baseline data production requirements for conducting a landslide risk assessment at different levels (such as the river basin level, local government level, community level, etc.). For example, the Department of Roads should collect data related to occurrence of landslides associated with the road network, including instability type, location, date, time of the incident, type and volume of the displaced material, losses and damages, rainfall during the day of the event and accumulated rainfall for three days, seven days, etc. before and after the event, date of repair and repair cost, etc.

Data management is the next important aspect of the risk assessment that should be taken into consideration. This includes record keeping of baseline data, a systemized process for verification and data maintenance. The respective national agency is responsible for record keeping (for example, the Department of Roads should keep all landslide records related to the road network), carrying out necessary verifications and maintaining a database that is easily accessible for user agencies. The sector level agencies should be designated to provide their own baseline data. For example, the Department of Local Governments will provide housing, road and related infrastructure data within each local government area, landslide inventory data, data on precipitation, losses and damages, landslide induced repair costs, etc. covering each local government area.

Every country has a process for developing national census data and it contains socio-economic data of population. A national census is usually conducted every ten years. The census is an opportunity and cost-effective way for gathering exposure and vulnerability data and that can be used in landslide (or multi-hazard) risk assessment. This can be achieved if authorities can be persuaded to include a relevant set of questions in the field data collection forms used during the national census. The National Disaster Management Office can work with the respective agency responsible for national census in advance for extending assistance in collecting data. That way national census data can be utilized in conducting a multi-hazard risk assessment that includes a landslide risk assessment.[1] Aggregated data provided by the national Census for the lowest admin unit can be used for Risk assessment of the respective area and same method can be used for assessment in any other scale too. There are numerical statistical methods to make them current for any following year, thereafter.

Many of the data sets used for landslide risk assessment are being produced by government agencies under different projects. However, there is a notable reluctance to share data for purposes other than for what is intended, including for landslide risk assessment. As data sharing can be challenging, steps must be taken to streamline the data sharing process among the user agencies. Protocols for data sharing should be enacted to avoid copyright issues, provide acknowledgements, and meet the costs for data production and verification, database maintenance, etc. A data-sharing agreement between agencies should include a formal contract that clearly defines the data that is being shared and how that data can be used for risk assessment related functions. The agreement also helps to prevent miscommunication between the data provider and receiving agency. Various mechanisms can be used for data sharing. Web-based data sharing is now becoming more popular due to cost effectiveness. If web-based data is used, authorities should all be in accord as it is important to use common software for data presentation and sharing (for example, QGIS for GIS software and GeoNode for web-based geospatial data sharing).

8.2. Designate an agency to provide dedicated landslide related work and assessment

In the majority of ASEAN countries, there is a body for coordinating disaster management related activities. A dedicated National Disaster Management Organization (NDMO) is usually established with a legal mandate for providing human and other resources for disaster management operations. Many ASEAN countries, however, do not have the capacity or a dedicated agency to handle specific technical issues related to major hazards prevailing in the country, including capacity for landslide disaster risk management purposes.

The NDMO can make a recommendation to the government to establish a dedicated agency or agencies to work specifically on landslide DRR functions and responsibilities. The agency will be tasked with the following key landslide DRR functions, among others.

- Landslide early warning
- Landslide hazard and risk mapping
- Landslide risk minimization activities that may include
    - Structural mitigation
    - Enhancement of community preparedness to ensure safety in areas with moderate landslide hazards
    - Promotion of resilient construction practices in landslide prone areas
    - Human settlement planning, including resettlement of vulnerable people living in high landslide hazard prone areas
- Recovery project implementation after large scale landslide disaster events

The designated agency should be staffed with a multi-disciplinary team (for example, covering engineering geology, geotechnical engineering, structural engineering, land use planning, GIS and Remote sensing, social science, economy, etc.) that will focus on mandated landslide functions and responsibilities and make appropriate recommendations to the government (local, district, provincial, national) for managing landslide risk. The Department of Mineral Resources in Thailand and the Vietnam Institute of Geosciences and Mineral Resources are examples of institutions that provide dedicated services for landslide risk management.

8.3. Conducting dedicated multi-level landslide risk assessment research

This JAIF DRR-CCA project has concentrated on stakeholder capacity building for conducting landslide risk assessments at the regional level as a decision support tool for authorities engaged in development practice. It has also worked to provide landslide risk assessment and landslide disaster risk reduction understanding at the community level. Various constraints, including time allocation and resource availability, resulted in the JAIF DRR-CCA project team being able to provide on-the-ground input in only two ASEAN countries – Lao PDR and Myanmar – and unable to consider other landslide risk assessment levels, scales and approaches, such as the deterministic approach. Therefore, dedicated and ASEAN-led research on landslide risk assessment is necessary in the future. Landslide risk assessments are also dynamic in nature, and continuity of data production and cost-effective data application is a pre-requisite. The dedicated landslide technical institutions should coordinate closely with the national disaster management organizations, academia and other relevant stakeholder agencies on landslide risk assessment research and methodology review and revision for different development projects at various levels. The findings from these reviews and revisions can serve as "best practices" examples and should be shared throughout ASEAN.

8.4. Sharing landslide risk knowledge widely and bridging information gaps

As shown in these guidelines, a large number of organizations are involved in landslide risk assessment related data production. Additionally, many institutions are involved in risk assessment data application and utilization. ASEAN countries use risk knowledge for landslide risk management in communities. As the primary stakeholders, these communities depend on risk knowledge for their routine functions. Landslide risk knowledge therefore must be shared with the general public in a simplified form through dedicated awareness creation programs.

Risk knowledge programs and sharing must recognize that different stakeholders use risk information for different purposes and it is therefore essential to map these information needs and share risk knowledge with the designated agencies. A sample of risk knowledge purposes is provided below.

- General resilience building through identification of geo-political areas affected by landslide hazards.
- Risk management scheme design through analysis of potential disaster scenarios in sectors that can potentially be affected, such as the economy, population, infrastructure, etc.
- Estimation of physical damage value and economic losses after potential disaster events.
- A quantitative basis for defining financial needs and priorities for economic recovery and reconstruction in case of a disaster event.
- Analysis of a government's capacity to meet its own post-disaster needs and to identify external assistance needed, such as for international cooperation for immediate and long-term recovery.
- Determination of disaster impacts on overall economic development and macro-level planning decisions.
- Assignment of a baseline for monitoring risk reduction measure progress.
- Defining changes or modifications to public policies to lessen disaster impact and facilitate economic recovery after disaster events.

Current mandates, roles and stakeholder agency functions must be critically evaluated, and agency needs identified. This will help identify gaps and produce recommendations for tailor made outputs, agency organized risk knowledge forums, capacity building, and enhancing inter-agency coordination arrangements. The country NDMO has primary responsibility for promoting risk knowledge. In terms of landslide risk, however, technical organizations involved in the assessment will likely provide much of the knowledge.

8.5. Landslide risk assessment data application in decision support functions and practice

Landslide risk assessment data can be used in a number of decision support functions, as shown below.

- Land use zonation and zoning ordinances. Example: Limiting development in high risk areas and encouraging development in low risk areas.
- Building codes and bylaws. Example: Imposing building controls depending on risk levels to protect existing and new development against hazards.
- Land Acquisition. Examples: Avoiding purchase of land unsuitable for development, rehabilitating high-risk lands, using open spaces for emergency operations, etc.
- Relocation. Example: Mandatory or voluntary relocation of affected families to safe areas.
- Subdivision Regulations. Example: Not allowing sub-division of sloping land into smaller plots.
- Property Taxation. Example: Offering private developers household tax breaks for the added cost of building to a higher level of hazard resistance.

The dedicated technical agency could assume the lead role in susceptibility mapping and risk assessment knowledge management interventions to promote risk assessment development planning data application and mainstreaming at sector, agency and local government levels. Knowledge forums and capacity building programs to improve risk knowledge and address information gaps among the stakeholders (depending on their decision support function needs) are a necessity.

8.6. Agency capacity building to promote landslide risk assessment data application in development practice

The Sendai Framework for Disaster Risk Reduction (SFDRR) demands that all stakeholders focus on establishing and increasing capacity to manage their country's disaster risk. Capacity development issues and measures must be an integral part of the landslide disaster risk reduction action agenda in order to achieve the SFDRR's stated priorities. Increasing capacity is important for risk assessment-based knowledge creation. Whether directed toward individual awareness enhancement, knowledge and skills improvement, strengthening organizational and institutional risk assessment structures, or fostering a more conducive risk reduction environment, improvement in both the mindset of stakeholders (decision makers, etc.) and the approach is vital.

The Sendai Framework highlights the need for DRR capacity development in institutions and individuals, not only at the national but also at sub-national and local levels. It is therefore essential to have a strategic approach for capacity building in landslide risk assessment for landslide risk management professionals. In the same way, capacity building should target new technology applications, sharing of experience and continual awareness and knowledge attainment. Landslide risk assessment training should be designed to focus on theoretical understanding of risk assessment methodologies, knowledge and data gaps, and skills and competencies.

A partnership approach can ensure risk assessment capacity building is a collective effort. This approach will be cost effective and more efficient. For example, several ASEAN country university post graduate institutions offer post graduate courses with landslide risk management related major subjects and/or as dedicated programs. Some training institutions also offer online landslide risk management courses. These courses can benefit those in remote locations that want to gain knowledge on this topic. University programs and courses on risk assessment will build landslide risk assessment capacity while feeding into assessment efforts on the ground. These efforts should be made part of the strategic risk assessment capacity building approach.

8.7. Promote inter-agency coordination for managing landslide risk

Landslides can be triggered by natural causes: rainfall, hydrology, underlying geological formations such as rock type and joint pattern, as well as rock soil and land weathering, are natural landslide triggers. Though they were previously perceived as isolated, low vulnerability events that occurred mainly due to these natural factors, urbanization, rapid population growth, inappropriate land management, and extensive land degradation caused by uncontrolled land use practices in hilly areas have all contributed to an increase in landslide events. Human-caused destructive landslides have become more frequent and widespread in several ASEAN countries, resulting in high victim numbers and considerable socio-economic impacts.

Landslide risk reduction planning and implementation should be holistic and focus on both those that contribute either positively or negatively to risk creation, including stakeholder agencies involved in the development process. It is essential to have good coordination between NDMOs and these stakeholder agencies in order to promote application of risk knowledge in their activities.

The country NDMOs should be responsible for knowledge management interventions to promote risk assessment data application in development planning and mainstreaming at sector, agency, and local government levels. The active involvement of specialized agencies, academia, etc. will help develop and systematize the risk knowledge sharing process. Managing landslide risk will only be effective if all relevant stakeholders, including government agencies and communities, are proactively involved and engaged in the decision-making process and implementation. Good coordination should therefore be promoted throughout the entire process.

Photo: Phoukhoun, ASEAN DRR-CCA

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