Disaster Management Research Roadmap for the ASEAN Region

ASEAN Science-Based
Disaster Management Platform (ASDMP) Project

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The ASEAN Science-Based Disaster Management Platform (ASDMP) project aimed to promote the involvement of science in policy development and policymakers in the research process for disaster management and risk reduction in the ASEAN region.

We would like to acknowledge.....

- all of the organizations that were willing to meet with us to discuss disaster management issues during our country visits,
- the individuals that responded to our Research Roadmap Survey,
- our distinguished participants who attended one of our various project events,
- other disaster experts consulted in the development of this roadmap,
- ASEAN Committee on Disaster Management,
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- AHA Centre,
- the Mission of the Republic of Korea to ASEAN, and...
- the ASEAN-ROK Cooperation Fund.

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Table of Contents

Message from the APCC Executive Director

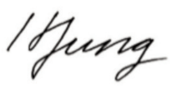
The ASEAN region is one of the most disaster-prone regions in the world, and extreme climate events are projected to increase in frequency and intensity due to climate variation and change.

We have seen the impacts that proper preparation and resilience -building efforts can have in the face of disaster events. The APEC Climate Center believes that science and policy, when merged and effectively utilized together, can truly enhance disaster risk reduction and disaster management. Through the ASDMP project, funded by the Republic of Korea government, the APEC Climate Center has worked closely with the AHA Centre, ASEAN Secretariat, and the ASEAN Committee on Disaster Management to enhance DRR and DRM in the region.

This research roadmap provides a guideline on a potential process that will help achieve the ASEAN region's goal of becoming a global leader on disaster management by 2025. The ASDMP project team has travelled the ASEAN region to ensure the reflection of local knowledge in this roadmap, and surveys have been distributed widely in an attempt to fully understand the status of DRR and DRM in the region.

This roadmap has identified key research and initiatives that need to take place in the short and long term on both the country and regional level, in order to greatly enhance resilience to disasters in the ASEAN region.

APCC would like to thank the Republic of Korea government, AHA Centre, ASEAN Secretariat, the ASEAN Committee on Disaster Management, and the respective governments of the ASEAN Member States for their active participation and support throughout the project duration.



Dr. Hong-Sang Jung
Executive Director
APEC Climate Center

Message from the ACDM Chair

The ASEAN region sits between several tectonic plates, which cause many extreme climate events such as earthquakes, volcanic eruptions, and tsunamis. Also being between the Pacific and Indian oceans causes seasonal typhoons. The ASEAN region is prone to almost all types of natural disasters including typhoons, floods, earthquakes, tsunamis, volcanic eruptions, landslides, forest fires, epidemics, and droughts. These extreme climate events often transcend the boundaries of individual nations, and that is why we must work together across boundaries to limit the potential damages of these events.

Therefore, the ASEAN Socio-Cultural Community Blueprint 2025 stipulates on the paragraph D.1. that: A Disaster Resilient ASEAN that is able to Anticipate, Respond, Cope, Adapt, and Build Back Better, Smater, and Faster.

I still remember my participation in the Kickoff Workshop for the ASEAN Science-Based Disaster Management Platform Project (ASDMP), which was taking place between 30th-31st March 2016 in Busan, Korea.

One of the above-mentioned workshop's objectives is to Increase APCC's network in the ASEAN region to increase the likelihood of cooperation and collaboration not only on the ASDMP Project but also on the future needs/projects. Today the objectives have been translated into concrete work. The Research Roadmap is an outstanding result, because this Disaster Roadmap management creates hope for all ten ASEAN Member States to use this as a guiding process for achieving the goal of becoming a global leader on Disaster Management by 2025.

On behalf of the ASEAN Committee on Disaster Management I would like to extend my gratitude and sincere thanks to the Republic of Korea Government, APCC, ASEAN Secretariat, AHA Center, and the respective organisations, and especially all of the experts for their close and fruitful contributions to the Research Roadmap.

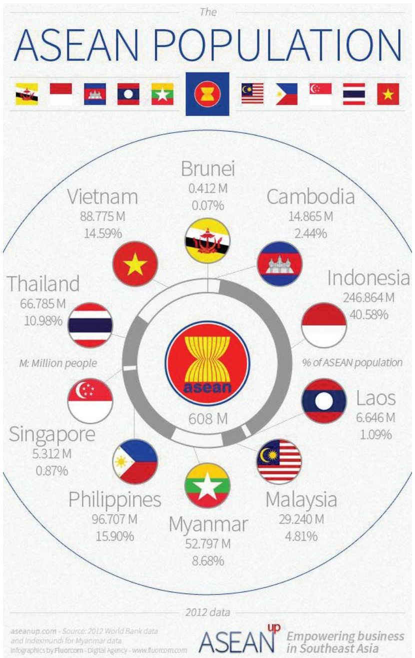
Mr. Prasong VONGKHAMCHANH
Director General of Social Welfare Department
Ministry of Labor and Social Welfare of Lao PDR
Chair of the ASEAN Committee on Disaster Management

Introduction

ASDMP Project and Broad Objectives

The Association of Southeast Asian Nations (ASEAN) includes a total of 608 million people that reside the region. These countries are also located in the Asia-Pacific region, which is highly vulnerable to the impacts of extreme climate events. Between 2002 and 2011, 40% of all reported disasters occurred in Asia. In 2011, Thailand was impacted by floods that caused massive devastation including the death of 813 persons and economic losses that amounted to USD 46.5 billion, affecting more than 13 million people (Jha & Stanton-Geddes 2013, World Bank 2012).

Figure 1. The population of ASEAN and each of its member countries using 2012 World Bank data. (ASEANup 2014)



Due to its disaster-prone locations, it is imperative to equip the ASEAN countries with the necessary tools to inform its disaster risk management (DRM) policies. In 2011, due to improved disaster preparedness in Indonesia, a 6.7 Richter scale earthquake's consequences were limited to the deaths of two persons (Davis 2015). This encouraging news illustrates that projects that inform ASEAN DRM policy-making processes can decrease the effects of extreme climate events.

Following this, the ASEAN Science-Based Disaster Management Platform project (ASDMP) seeks to promote "scientific and technical research programmes that study the causes and consequences of disasters and facilitate activities that promote and support the development of the means, methods, techniques, and equipment for disaster management, particularly in risk reduction" (ASEAN 2013). This project is funded by the Government of Korea through the ASEAN-ROK Special Cooperation Fund, and is currently being implemented by the APEC Climate Center (APCC) and the ASEAN Coordinating Centre for Humanitarian Assistance (AHA Centre).

Research Roadmap

This disaster management research roadmap for the ASEAN region was created in the hopes that it will guide the process of achieving the goal of becoming a global leader on disaster risk management (DRM) and disaster risk reduction (DRR) by 2025. The principal objective of the Roadmap is to prioritize the research that needs to be done in the ASEAN region in order to enhance DRM and management practices and policy relevant to the ASEAN member states.

The roadmap focuses on the needs of both the scientists and policymakers focusing and working on the ASEAN region. It provides a guiding framework for the future research topics that may be identified and created into potential projects that will contribute to decision-making processes in the disaster and other relevant sectors. While we have made every effort to be as comprehensive as possible as well as reflect the current disaster sector status in each ASEAN member state, we recognize that with the limited time, we may have not been able to fully encompass all ASEAN member state needs. We also recognize that time will lead to changes in emphasis and focus as well as national priorities, so this document should be reviewed from time to time in order for it to remain relevant.

We would also like to emphasize that the success of the Roadmap will be dependent on the willingness of the scientists and policymakers in the ASEAN region to utilize the roadmap together to determine which projects they would like to collaborate on together. Without this imperative communication, the gap between the science and policy communities will remain and it will remain difficult to develop scientifically informed disaster management and DRM policies.

It is also recognized that no single approach or suit all ASEAN member countries. We have tried to address this issue through the development of separate country-level roadmaps as well as a wider regional-level roadmap. We hope that using this document as a guide, each ASEAN country as well as groups of countries as a regional effort, will develop its own implementation plan to incorporate science into their policy-making processes as well as policy into research topic-determining processes.

Background

Background

Current DRR/DRM Issues in ASEAN

The ASEAN region is located between several tectonic plates including the Indian Plate, Australian Plate, Eurasian Plate, Philippines Plate, and Carolina Plate (NASA, 2002; OCHA, 2014), which is a part of the "Ring of Fire" where earthquake, volcanic eruptions, and tsunamis induced by geophysical factors have frequently occurred. Since the ASEAN region is also between the Pacific and Indian Oceans, it is frequently affected by tropical cyclones and tsunamis.

Almost all disaster types have devastating impacts on ASEAN countries. Disaster risk statistics in ASEAN from 1970 to 2009 indicate that floods and storms have been the most frequent disaster types, and that storms, tsunamis, and earthquakes are the most impactful in terms of fatalities (Table 1; UNISDR, 2010).

Table 1. Disaster risk statistics during 1970-2009 in ASEAN (UNISDR, 2010)

Disaster Type	Number of Disasters per Year	Total Deaths	Deaths per Year
Flood	10.85	17,800	445.0
Storm	9.65	184,063	4,601.6
Epidemic	2.28	7,294	182.4
Landslide	2.05	5,058	126.5
Forest Fire	0.45	310	7.8
Drought	0.98	1,337	33.4
Tsunami	0.15	92,021	2,300.5
Volcano	1.33	1,380	34.5
Earthquake	2.58	105,735	2,643.4

Reported disasters during the more recent years can be examined in the ASEAN Disaster Information Network (ADInet) run by the AHA Centre. From 3 January 2012 to 16 July 2017, total 893 disasters were reported to AHA Centre (ADInet, 2017; Figure 2). Among them, there were 558 flood, 94 landslide, 166 wind, 82 storm, 13 drought, 15 volcano, and 35 earthquake events reported (ADInet, 2017).

Figure 2. Number of reported disasters in ASEAN during January 2012 to July 2017 (ADInet, 2017)

Economic loss and fatalities are also important indicators of disaster severity in addition to the event frequency. The 2011 flood and landslides event in Thailand was ranked as the 4th costliest disasters worldwide (2007-2016) with its overall economic losses estimated at 43,000 million USD, and 813 fatalities (NatCatSERVICE, Munich Re, 2017). Cyclone Nargis and the accompanying storm surge in Myanmar in May 3008 was ranked to be the 2nd costliest disaster worldwide with its overall economic losses estimated at 4,000 million USD and 140,000 fatalities (NatCatSERVICE, Munich Re, 2017).

Climate change may also increase the frequency and severity of disasters. According to the Intergovernmental Panel on Climate Change (IPCC) fifth assessment report, precipitation near the centers of tropical cyclones making landfall in Southeast Asia will likely become more extreme, and monsoon-related precipitation extremes will very likely increase in the Southeast Asia region (Hijioka et al., 2014). This research roadmap will focus on seven different types of disaster events prioritized by the ASEAN region: (1) drought; (2) earthquake; (3) flood/inundation; (4) landslide; (5) typhoon; (6) volcano; and (7) tsunami.

— Drought

Droughts are recurrent disasters that can have devastating impacts on humans and ecosystems (Dai and Zhao, 2016; Kim and Rhee, 2016). Drought is a temporary dry period characterized by below-average precipitation. The relative definition of drought implies that droughts can occur even under the wet and humid climate in Southeastern Asia (Dai, 2011). Among the different types of climatological disasters, drought impacts seem to be the largest due to its long duration and continuing effects on the water sectors (Wilhite et al., 2014; Wilhite, 2000). The root cause of drought is a lack of precipitation originated from natural variations (e.g., oscillation of sea surface temperatures) and human-made effects (e.g., anthropogenic greenhouse gas emission). Globally rising surface temperature amplifies atmospheric moisture demands, indicating that the feedback mechanism between the atmosphere and land surfaces will make future drought events more rapid and intense (Dia and Zhao, 2016; Cook et al., 2014; Trenberth et al., 2014).

Table 2. Drought Statistics during 1987-2016 (Source: EM-DAT, 2017)

Country	Number of Events	Total Deaths (persons)	Total Affected (persons)	Total Damage (1,000 USD)
Brunei Darussalam	0	0	0	0
Cambodia	6	0	9,050,000	138,000
Indonesia	4	683	1,080,000	89,000
Laos	4	0	750,000	1,000
Malaysia	2	0	2,205,000	0
Myanmar	0	0	0	0
Philippines	6	8	4,038,069	148,852
Singapore	0	0	0	0
Thailand	11	0	29,982,602	3,724,300
Vietnam	6	0	7,860,000	7,399,120
ASEAN	39	691	54,965,671	11,500,272

The disaster records during 1987-2016 in Table 2 identify Thailand, Cambodia, Vietnam, Philippines, Malaysia, Indonesia, and Lao PDR as drought-prone countries in the ASEAN region. Although floods may seem to be the most frequent and influential natural disaster within the ASEAN region, consequences of drought events might be underestimated due to the unrecorded impacts of droughts. The creeping nature of droughts can hinder sensing its onsets and termination (Wilhite et al., 2014; 2000). Drought impacts may linger even after the termination of a drought event (Mishra and Singh, 2010). Thus, there are likely unrecorded damages from past droughts across the ASEAN region. It should be noted that drought can not only limit water resources, but also energy generation in ASEAN countries (Shadman et al., 2016). Damages from the chain effects of precipitation deficiency may be missing from the disaster statistics.

In Southeastern Asia, hotspots of decreasing precipitation are in Cambodia, Vietnam, Lao PDR, Myanmar, and Indonesia (Polpanich, 2010). The atmospheric moisture demand is increasing across the ASEAN regions with globally rising temperatures. In the IPCC 4th assessment report, Philippines, Vietnam, Cambodia, Lao PDR, Thailand, and Indonesia were identified as climate change hotspots, indicating that the climate change scenarios seem to indicate increasing drought risk. Approximately 105 million people are prone to water stress in the Mekong region (Arnell, 2004). Several global drought assessments (e.g., Dai and Zhao, 2016; Zhao, 2016; Dai, 2013; Dai, 2011) are also consistently reporting increasing drought risks over the hotspots due to climate change.

In scientific communities, one of the main issues of droughts in Southeastern Asia is that many recent drought events were strongly associated with El Nino-Southern Oscillation (ENSO). ENSO-related effects have been particularly significant for March-May when ENSO events decay, suggesting predictability of post-Nino Aprils to prepare for the adverse effects of water and heat stresses. Another important issue is that drought and rising temperatures disrupt not only agricultural production, but energy generation. Low water availability and high temperature of cooling water can limit energy generation in all types of power plants, and thus may impair human livelihood significantly. In general, economies of ASEAN countries are highly dependent on non-irrigated agriculture. Sustaining food security and providing job opportunities outside of agriculture are also major issues for reducing drought impacts.

— Flood / Inundation

Flood and inundation are one of the most destructive natural hazards (Michel-Kerjan and Kunreuther, 2011). With urbanization and climate change, the frequency and magnitude of flood and inundation events are increasing in many parts of the world (Mallakpour and Villarini, 2015). In particular, the ASEAN region is extremely flood-prone because of frequent typhoons and tropical storms. For example, the annual average flood occurrence during 1970-2009 was 10.82/year in ASEAN region, which is ranked the highest among nine types of natural disasters (UNISDR, 2012).

ASEAN member countries are located in a highly vulnerable area to the impacts of extreme climate events. As stated previously, 40% of all reported disasters in the world occurred in Asia between 2002 and 2011. Table 3 shows the statistic summary of floods that occurred in the ASEAN region from 1987 to 2016. Flood is the most common and repetitive natural disaster in the ASEAN region. For instance, flood events are the most frequent when compared to other natural disasters like earthquake, drought, landslide, typhoon, volcano and tsunami. From 1987 to 2016, 498 flood events were reported, which is equivalent more than 16.6 events per year in comparison to other disaster types with less than 9.6 events per year (typhoon: 9.6; landslide: 3.3; earthquake: 3.2; volcano: 1.5; drought: 1.3) (EM-DAT, 2017). During this 30 year period, there were a total of 498 flood events in the ASEAN region and 17,719 deaths were reported, with a total of 62.2 billion US dollars in damages. Therefore, it is obvious that establishment of flood mitigation and countermeasures should be an urgent task in the ASEAN region.

Table 3. Flood Statistics during 1987-2016 (Source: EM-DAT, 2017)

Country	Number of Events	Total Deaths (persons)	Total Affected (persons)	Total Damage (1,000 USD)
Brunei Darussalam	0	0	0	0
Cambodia	18	1,641	13,275,587	1,419,100
Indonesia	145	4,759	7,494,336	6,706,909
Lao PDR	19	153	3,907,011	153,878
Malaysia	37	197	865,899	1,417,000
Myanmar	22	622	3,536,342	257,655
Philippines	120	2,280	26,926,207	3,527,402
Singapore	0	0	0	0
Thailand	65	3,443	48,666,009	44,621,108
Vietnam	72	4,624	24,873,245	4,111,507
ASEAN	498	17,719	129,544,636	62,214,559

— Landslide

Most parts of the ASEAN region have hot and humid tropical climates, with the exception of the mountainous areas. The majority of the population lives in low coastal areas, floodplains, and deltas, putting them at high risk of disasters. Despite rapid economic growth, the region has challenges related to urbanization and environmental degradation, which can increase risk exposure and vulnerability of the population (GFDRR, 2012).

Landslide involving bedrock hillslope erosion can be caused by rising pore water pressure induced by extreme rainstorms (De et al., 2002). The main causes of landslides can be divided into internal factors and external causes. Internal factors include natural factors such as geological structure, topography, soil, and clinical factors. External causes include natural factors such as extreme rainfall, river erosion and coastal erosion, earthquake, etc., and artificial factors such as cutting soil, logging, complex construction, and quarrying development. Among these, steep slopes are the most important factor that makes a landscape susceptible to landslides. By one estimate, landslides triggered by heavy rain kill roughly 4,600 people each year (NASA, 2017). Scientists and policy makers are trying to find appropriate solutions to reduce that number. According to the disaster statistics, Indonesia has the highest percentage of population at landslide risk in the ASEAN region, followed by the Philippines and Myanmar (EM-DAT, 2017).

Figure 3 shows a map of global landslide susceptibility produced by the Earth Observatory in the National Aeronautics and Space Administration (NASA), which confirms that the ASEAN countries are vulnerable to landslides. This is part of a broader effort to establish a hazards monitoring system that combines satellite observations of rainfall from the Global Precipitation Measurement (GPM) mission with an assessment of the underlying susceptibility of terrain (Kirschbaum et al., 2017).

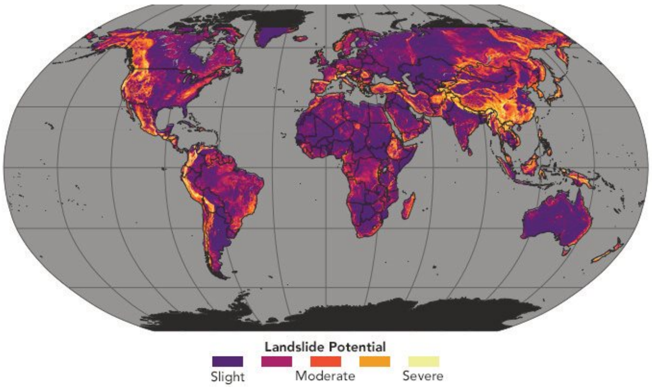


Figure 3. A map of global landslide susceptibility (Earth Observatory, NASA: https://earthobservatory.nasa.gov/IOTD/view.php?id=89937)

Table 4. Landslide Statistics during 1987-2016 (Source: EM-DAT, 2017)

Country	Number of Events	Total Deaths (persons)	Total Affected (persons)	Total Damage (1,000 USD)
Brunei Darussalam	0	0	0	0
Cambodia	0	0	0	0
Indonesia	49	1,807	385,936	146,745
Lao PDR	0	0	0	0
Malaysia	5	168	291	0
Myanmar	7	205	147,582	0
Philippines	28	2,190	317,539	33,281
Singapore	0	0	0	0
Thailand	3	47	43,110	0
Vietnam	6	330	39,074	2,300
ASEAN	98	4,747	933,532	182,326

The ASEAN region is geographically and hydro-meteorologically diverse. Most parts of the region have hot and humid tropical climates. Due to the high population density in the ASEAN region, buildings and residential areas are often located in hilly steep slopes in mountainous areas, putting them at high risk of landslide. According to the statistics in Table 4, Indonesia is the most vulnerable to landslides in the ASEAN region, followed by the Philippines, Myanmar and Vietnam. The western and eastern areas of Java Island, Indonesia, and the Philippines are the hotspots of landslide in the ASEAN region (Yusuf and Francisco, 2009).

Table 4 shows a statistic summary of landslides in the ASEAN region from 1987 to 2016. During these 30 years, there was a total of 98 landslides (3.27 per year), 4,747 deaths (158 per year), 933.53 thousand impacted persons (31.12 thousand per year), and total damages of 182.33 million US dollars (6.08 million per year). Indonesia experienced the most landslide events with 49 events, followed by the Philippines. In contrast, Brunei, Cambodia, Lao PDR, and Singapore have not experienced any landslide events based on EM-DAT statistics. The other countries, Malaysia, Myanmar, Thailand, and Vietnam, experience landslides, but not frequently.

The occurrence of landslides is likely to change under future climate change, and its impacts and damages can also shift. According to various climate models and several scientists, it is also projected that more frequent landslides may be induced by an increase in intensity of precipitation due to climate change. In particular, human activities in steep slopes due to population growth and urbanization in the ASEAN region are contributing to the possibility of increases in landslide events. As such, the landslide statistics and the results of the aforementioned scientific research emphasize the importance of timely and effective landslide DRR based on scientific research in the ASEAN region.

— Typhoon

Typhoon is one of the most destructive natural disasters due to its wide range of impact through strong winds and torrential rain. Many ASEAN countries are located within or close to typhoon active regions, and thus, typhoons pose a great threat to the ASEAN community. In particular, the recent increase in population and infrastructure in the coastal areas of ASEAN increase the risk of typhoon-related damages and disruption (Knutson et al., 2010).

The primary impacts of Typhoon events include storm surge, strong wave, strong winds, and heavy rain. Destructive influences of typhoons are dependent on its frequency, intensity, and location. Strong winds and heavy rains have the potential to trigger floods and landslides. Usually the most severe damages from typhoons are attributed to storm surge and waves that may result in coastal floods. Since most fatalities are caused by storm surges in coastal areas, effective early warning systems and DRM mechanisms can reduce the number of casualties (World Bank and United Nations, 2010). Therefore, accurate and reliable typhoon track and intensity prediction are essential for successful disaster preparedness and management.

With increased scientific understanding about typhoons, typhoon forecast skill is also enhanced. In recent years, the availability of suitable data has increased and more advanced forecasting techniques have been developed (Roy and Kovordanyi, 2012). However, there is still a lack of knowledge on the details of typhoon initiation and development processes as well as their tracks. Furthermore, direct and indirect impacts of climate change on typhoon tracks and intensity and the associated typhoon risks are uncertain.

Fortunately, mortality caused by typhoons has been decreasing recently in the ASEAN region. This trend seems to be due to improved technologies and DRM with improved access to information. On the other hand, typhoon-related socio-economic damage has been increased (Yang 2008; World Bank and United Nations, 2010) being attributed to fast economic growth and poverty reduction in ASEAN countries. These features suggest that that it is important to integrate typhoon risk information in order to reduce economic damages and minimize human casualty.

While national and state level strategies and mitigation plans for typhoon disasters have been enhanced greatly, communications among different levels of governance (e.g., between national/state governments and local agencies/communities) still need to be improved. In particular, due to the trans-boundary impact of typhoons, intergovernmental or regional cooperation within the affected regions are critical in terms of sharing typhoon information and knowledge as well as effective preparedness and DRM.

Table 5. Typhoon Statistics during 1987-2016 (Source: EM-DAT, 2017)

Country	# of events	Total Deaths (persons)	Total Affected (persons)	Total Damage (1,000 USD)
Brunei Darussalam	0	0	0	0
Cambodia	3	44	178,091	10
Indonesia	1	0	1,315	0
Lao PDR	3	64	1,397,764	103,650
Malaysia	2	272	6,291	53,000
Myanmar	5	138,698	2,830,125	4,067,688
Philippines	189	30,696	134,033,748	19,487,415
Singapore	0	0	0	0
Thailand	18	819	3,816,896	744,823
Vietnam	68	7,976	25,443,955	6,697,857
ASEAN	289	178,569	167,708,185	31,154,443

According to the typhoon statistics in Table 5, the most vulnerable country to typhoons in the ASEAN region is the Philippines, followed by Vietnam and Thailand. This is attributed to the fact that most typhoons affecting the western part of the Indochina Peninsular originate in the western tropical Pacific near the Philippines. As a result, Philippines is affected by an average of 6.3 typhoons per year. In contrast, little impact is found in Brunei, Singapore, and Indonesia. Cambodia, Malaysia, Laos, and Myanmar are not frequently affected by typhoons. However, even one single typhoon event can result in serious causalities and socio-economic damage, as seen in the case of Typhoon Nargis in Myanmar in May 2008, which resulted in 138,000 fatalities and 10 billion US Dollars in damages.

Typhoon frequency, path, intensity and season can change over time, as suggested by the strong inter-annual and multi-decadal variations in the typhoon landfalls in Philippines and Vietnam (Chan and Xu, 2009). It is also projected that more intense typhoons may be induced by global warming (IPCC, 2012).

— Earthquake, Volcano, and Tsunami

An earthquake is caused by a sudden movement of the Earth releasing accumulated energy from tectonic plates. Most earthquakes occur at the boundaries where the plates meet, and less than 10% of all earthquakes occur within the plate interiors. Although the released energy may be generated from volcanic eruptions or man-made explosions, most are from dislocations of segments of the Earth's crust. Seismic waves generated during the breaking processes travel outward from the source of the earthquake (Shedlock and Pakiser, 1995). During the recent 30 years (1987-2016), earthquakes were responsible for more than 15,000 deaths from 96 earthquake events in the ASEAN region. There were more than 13 million persons affected, and the economic loss reached around 7.5 billion USD (Table 6). Impacts of earthquakes in the ASEAN region have been severe due to its location on the Pacific Rim which is the most affected area of seismic activity. However, not all ASEAN Member States are exposed to earthquakes: Indonesia has had the most earthquake activity in the last ten years, followed by Philippines and Myanmar. Thailand also experienced serious economic loss from only three earthquake events (EM-DAT, 2017).

Table 6. Earthquake Statistics during 1987-2016 (Source: EM-DAT, 2017)

Country	Number of Events	Total Deaths (persons)	Total Affected (persons)	Total Damage (1,000 USD)
Brunei Darussalam	0	0	0	0
Cambodia	0	0	0	0
Indonesia	72	12,162	7,968,448	7,066,456
Lao PDR	0	0	0	0
Malaysia	1	24	10	2
Myanmar	5	116	24,075	14,770
Philippines	15	2,871	5,552,800	441,401
Singapore	0	0	0	0
Thailand	3	2	17,539	62,000
Vietnam	0	0	0	0
ASEAN	96	15,175	13,562,872	7,584,629

Among recent earthquake events, the earthquake on 30 September – 1 October, 2009 was recorded to be the costliest and deadliest event in Southeast Asia between 2007 and 2016, with 1,195 people killed and an economic loss of 2,000 million USD (NatCatSERVICE, 2017).

Table 7. Five costliest earthquake events in Southeast Asia between 2007 and 2016 (NatCatSERVICE, 2017)

Date	Event	Impacted Country	Economic Losses (million USD)	Total Deaths (persons)
30 SEP – 1 OCT 2009	Earthquake	Indonesia	2,000	1,195
12 – 13 SEP 2007	Earthquake, Tsunami	Indonesia	380	25
25 OCT 2010	Earthquake, Tsunami	Indonesia	300	448
15 OCT 2013	Earthquake	Philippines	300	222
2 SEP 2009	Earthquake	Indonesia	250	80

Table 8. Five deadliest earthquake events in Southeast Asia between 2007 and 2016 (NatCatSERVICE, 2017)

Date	Event	Impacted Country	Economic Losses (million USD)	Total Deaths (persons)
30 SEP – 1 OCT 2009	Earthquake	Indonesia	2,000	1,195
25 OCT 2010	Earthquake, Tsunami	Indonesia	300	448
15 OCT 2013	Earthquake	Philippines	300	222
6 FEB 2012	Earthquake	Philippines	15	113
7 DEC 2016	Earthquake	Indonesia	100	104

Tsunamis, also known as seismic sea waves, are enormous ocean waves caused by underwater disturbance such as large earthquakes, landslides, or volcanic eruptions. Different from tidal waves, tsunamis carry extremely strong currents and can persist for many hours due to complex interactions with the coast (ITIC, 2017; USGS, 2017). Most tsunamis are caused by large earthquakes on the sea floor (ITIC, 2017).

Tsunamis are one of the most fatal natural disasters since it overwhelms coastal areas and flushes out everything located below its amplitude. Large tsunamis are critical geomorphic crises, as they cause extensive erosion, sediment transport, and deposition in only a few minutes (Paris et al., 2009). In addition, the waters that have been pushed into the land lead to flooding, causing damage to many people and property, and also causing salt water damage to agricultural lands.

In the ASEAN region, most tsunamis in the recent 30 years from 1987 and 2016 occurred in Indonesia (six out of nine events). Compared to other geophysical disasters, earthquakes and volcanic eruptions, fatalities per event and total damage per event are extremely high. The 9 tsunami events in the past ten years killed a total of 175,548 people, averaging 19,505 fatalities per event, and causing more than 6 billion USD in damages (EM-DAT, 2017).

Table 9. Tsunami Statistics (Source: EM-DAT, 2017)

Country	# of events	Total Deaths (persons)	Total Affected (persons)	Total Damage (1,000 USD)
Brunei Darussalam	0	0	0	0
Cambodia	0	0	0	0
Indonesia	6	167,052	590,684	4,506,600
Lao PDR	0	0	0	0
Malaysia	1	80	5,063	500,000
Myanmar	1	71	15,700	500,000
Philippines	0	0	0	0
Singapore	0	0	0	0
Thailand	1	8,345	67,007	1,000,000
Vietnam	0	0	0	0
ASEAN	9	175,548	678,454	6,506,600

On December 26th, 2004, there was a great earthquake 250 km southwest of Banda Aceh in northern Sumatra, Indonesia (Borrero, 2005). With a magnitude of 9.3, it was the second largest instrumentally recorded earthquake in history (Stein and Okal, 2005). The earthquake generated the Indian Ocean tsunami. Within hours of the earthquake, destructive waves radiating from the epicentre slammed into the coastline of eleven Indian Ocean countries, inundating coastal communities with waves up to 30 meters (98 ft) high, damaging countries from east Africa to Thailand and killing over 230,000 people in fourteen countries. It was one of the deadliest natural disasters in recorded history. Indonesia was the hardest-hit country, followed by Sri Lanka, India, and Thailand. Although the frequency of tsunami events in the ASEAN area is low compared to many other natural hazards, the Indian Ocean case serves as a reminder that the impacts of even one isolated event can be extremely high, showing the need for disaster preparedness.

Existing DRR/DRM Capacity and Policies in ASEAN

— Regional Efforts

The ten ASEAN Member States signed the ASEAN Agreement on Disaster Management and Emergency Response (AADMER) in July 2009 (entered into force on December 2010) as a regional framework for cooperation, coordination, technical assistance, and resource mobilization in all aspects of DRM and emergency response. AADMER is the first legally binding regional instrument in the world that is related to the Hyogo Framework of Action (HFA), showing ASEAN's firm commitment to the HFA. Many key aspects of DRM have been tackled by the implementation of the AADMER Work Programme 2010-2020.

— Brunei Darussalam

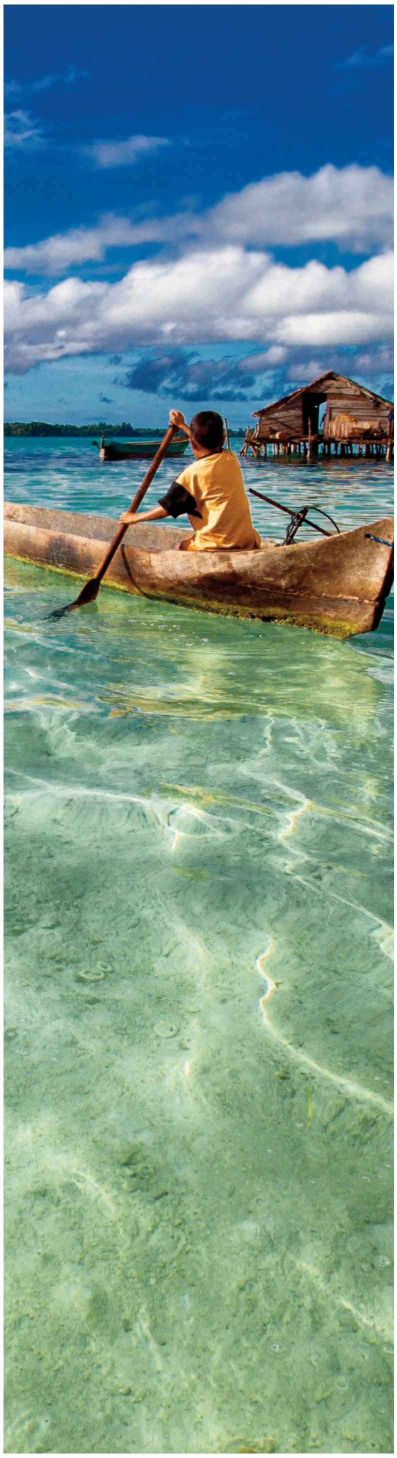
Since none of the types of disaster we are dealing with in this DRM research roadmap is relevant to Brunei Darussalam, existing DRR/DRM capacity and policies of this country were not included.

— Cambodia

Floods and droughts are the two major natural disasters in Cambodia. Cambodia is also vulnerable to typhoons and landslides. DRM mechanisms, frameworks, governance, and the corresponding rights and obligations, and resources and funds in Cambodia are supported by the Law on Disaster Management enacted in 2015. The law indicates the need for mainstreaming DRR by incorporating it into sector-wise policies. The National Strategic Development Plan (NSDP) 2014-2018 entrusted by the Ministry of Environment, prepares the climate change legal framework including the strategic and operational programs of each sector, providing strategic directions for the management of natural resources and environment, and the capacity development strategies for CCA and mitigation of the risks caused by natural disasters. The National Committee for Disaster Management (NCDM) established in 1995 administers and coordinates all DRM activities. The Ministry of Water Resources and Meteorology (MOWRAM) is responsible for managing river basins as well as surface and groundwater resources.

— Indonesia

Indonesia is one of the most disaster-prone countries in the world, regularly experiencing earthquakes, tsunamis, landslides, volcanic eruptions, floods, and droughts. Spread across 6,000 inhabited islands, communities in Indonesia face numerous different hazards, as well as differing levels of disaster response capacity, posing a challenge in preparing for and responding to disasters. Poverty, population growth, and rapid urbanization exacerbate these vulnerabilities, along with climate change and the resulting changes in rainfall patterns, storm severity, and sea level. The impact of the Indian Ocean tsunami led to the development of Law Number 24 of 2007 concerning Disaster Management (the DM Law). This law has carried out the new perspective on DRM: DRM not only in an emergency response context, but also as pre-disaster and post-disaster. The previous perspective of DRM emphasized only emergency response/relief. HFA monitoring became an instrumental part of advancing Indonesia's DRR agenda, including the development of the national DM Law in 2007 and the creation of Badan Nasional Penanggulangan Bencana (BNPB, "National Disaster Management Authority") in 2008, whose role is to coordinate the DRM efforts of the Government and stakeholders. Since 2007, the Indonesian government has developed a robust legal framework to strengthen DRM in the country by promulgating several laws, regulations, plans, and policies. Besides national laws, regulations, and decrees, Indonesia also conforms to the legally binding AADMER agreement. All 34 provinces of Indonesia have established provincial level Badan Penanggulangan Bencana Daerah (BPBD, "Regional Disaster Management Authority") and have prepared Rencana Penanggulangan Bencana (RPB), or the "Provincial Disaster Management Plan". More than 90 per cent of the districts and cities in Indonesia have their own local DRM agencies. BNPB continues to build the technical capacity of these BPBDs. Further work is needed to develop institutional frameworks that clearly define (a) the respective roles and responsibilities of national level ministries/agencies (horizontal) and between national, provincial and local governments (vertical); and (b) the overall bureaucratic steps and protocols required for managing disaster risks and events effectively. Disaster Risk Management Forums (FPRB) have been established in 19 provinces and 45 districts, consisting of government and civil society members. BNPB has included development of these frameworks in its work programme since 2012.



— Lao PDR

The major natural disasters experienced in Lao PDR are floods, droughts, and cyclones. The ASEAN Disaster Risk Management Initiative (2010) reported that floods have been the most frequent and significant during 1970-2009. The central and southern parts of Lao PDR along the Mekong River have experienced floods every year. In the Mekong River, the greatest flood rate was recorded in August 2008, and flood events have become more frequent during the last decade. Cyclones, one of the major causes of floods, affect the mainland of Lao PDR above 15°N especially in September and October. Typhoon Ketsana in 2009, for example, resulted in 16 deaths and 100 million USD in economic loss. Due to the Lao economy's high dependency on agriculture, Lao PDR is also vulnerable to drought impacts. A drought in 2003 recorded 16.5 million USD in economic losses in central and southern Lao.

The government of Lao PDR planned to graduate the least development status by 2020 via sustainable development. Improving preparedness for natural disasters and climate change is one stem of the national development goals. The legal framework for DRM is centered on the National Disaster Management Committee (NDMC). The National Disaster Management Office (NDMO) under NDMC plays a key role in assessing hazards and risks of natural disasters. The national strategic plan on DRM is based on the HFA and the AADMER, aiming (1) to integrate disaster risks into sustainable development policies, (2) to strengthen institutional capacities for resilience to hazards, and (3) to prepare efficient response and recovery programs. Some recent achievements from the national framework include establishment of the standard early warning system, education programs incorporated with DRR, cooperation with international partners (e.g., UN agencies), and more. However, there are still remaining issues on systematic data collection, assessment of low profile hazards, capacity building for probabilistic risk assessment, and mainstreaming DRR into poverty reduction strategies.

— Malaysia

Tropical storms and floods with or without landslides frequently affect Malaysia, while droughts also pose a threat. The National Security Council (NSC) Directive No. 20 (Policy and Mechanisms on National Disaster Relief and Management) promulgated in 1997, stipulates the mechanisms on DRM including responsibilities and functions of the relevant agencies under the integrated emergency management system, setting the main guideline for DRM in Malaysia. The Directive No. 20 prescribes the management mechanism to ensure effective coordination and mobilization of resources for DRM. Malaysia's 11th National Plan 2016-2020 is a strategic plan that paves the way to deliver the future of Malaysia, and focuses on climate resilient development that incorporates climate change adaptation (CCA) into policy and development planning, evaluation and implementation. Malaysia's National Platform for DRR was formalized in 2013, involving various stakeholders from the government as well as the private sector. Malaysia's 11th Five-year Plan (2016-2020) focuses on strengthening DRM across 5 phases (prevention, mitigation, preparedness, response and recovery). The Government of Malaysia, on August 26th, 2015, established the National Disaster Management Agency (NADMA) charged with taking over DRM from the NSC. The DRM mechanisms in Malaysia are operated at four levels: the Community Level, District Level, State Level, and Central/Federal Level. The Department of Irrigation and Drainage Malaysia (DID) of the Ministry of Natural Resources and Environment (NRE) has the direction of promoting River Basin Management.

— Myanmar

Myanmar is ranked as the most disaster-prone country in Southeast Asia according to the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA). In addition, the report of "Global Climate Risk Index 2016" found that Myanmar was one of the countries most affected by extreme weather and weather-related loss events during 1995 to 2014. The country has regularly experienced a wide range of hazards, such as cyclones, floods, earthquakes, storm surges, landslides, droughts, tsunamis, and smaller-scale disasters. According to the historical data, Cyclone Nargis in 2008 left around 140,000 people dead and/or missing, with an estimated 2.6 million people affected in the Ayeyarwady Delta region. The August 2012 flood in Myanmar displaced around 86,000 people and affected over 287,000 people. Also in November 2012, a 6.8 magnitude earthquake in northern Myanmar killed at least 16 people and injured 52, with over 400 houses, 65 schools, and 100 religious building damaged (OCHA, 2012)
.

The Relief and Resettlement Department (RRD) was established with the objective to provide relief for victims of natural disasters and to minimize loss of lives and property. It is a part of the Ministry of Social Welfare, Relief and Resettlement, Myanmar. And the Myanmar Department of Meteorology and Hydrology conducts weather forecasting (e.g., daily and monthly) and monthly met/hydro forecasting, and covers natural disasters such as severe weather, floods, cyclones, earthquakes, and tsunamis, while also operating their early warning system. The government stakeholders closely cooperate with international organizations and institutions to ensure a more systematic, inclusive and coordinated approach to DRM, preparedness and response.

— Philippines

The Philippines, by virtue of its geographic circumstances, is highly prone to natural disasters, such as earthquakes, volcanic eruptions, tropical cyclones and floods, making it one of the most disaster prone countries in the world. Presidential Decree PD1566, promulgated on 11 June 1978 is the current basis of the Philippines' DRM arrangements. PD1566 defines the National Disaster Coordinating Council (NDCC) as the highest policy-making body on matters pertaining to disasters, directly advising the President. National Disaster Coordinating Council (NDCC) member agencies are responsible for carrying out respective tasks and responsibilities, which include preparedness, mitigation, response, and rehabilitation. PAGASA and PHIVOLCS are members of the NDCC and their respective responsibilities are as follows:

- Philippine Atmospheric, Geophysical and Astronomical Services (PAGASA): continuing watch on environmental conditions to prepare daily weather forecasts, typhoon watches, and flood outlooks.
- Philippine Institute of Volcanology & Seismology (PHIVOLCS): issues advisories on earthquakes, volcanic activity, and tsunamis; identifies appropriate evacuation sites and organizes disaster control groups and reaction teams.

The National Disaster Risk Reduction Management Council (NDRRMC) adopted the National DRR Management Framework (NDRRMF) in 2011, a key component of DRR and sustainable development. It has overall responsibility for NDRRMC approval.

— Singapore

Singapore is the least disaster-prone county in the ASEAN region along with Brunei. Expected potential natural disasters are earthquakes, cyclones, floods, and smoke/haze; however, vulnerability to the disasters is generally low. DRM in Singapore is mainly focused on human-made disasters in its highly urbanized environment. Approximately 80 percent of the population resides in high-story buildings in small urban areas; hence, fires and epidemics are main challenges. However, earthquakes can occur through the Sumatran strike slope fault, floods can happen occasionally with heavy rains, and smoke/haze hazards from forest fires in Indonesia can cause severe visibility and health problems.

The leading agency for responsive DRM is the Singapore Civil Defense Force (SCDF). The main principles for DRM programs are (1) to strictly enforce comprehensive regulations on fire and building safety, (2) to develop emergency and contingency plans that should be in regular exercise and drills, (3) to educate community to properly respond to disasters, (4) to coordinate multi-agency efforts, and (5) to restore and rehabilitate injured people and affected areas. The DRM programs and activities are legally supported, for instance, by the Civil Defense Act 1986 and Fire Safety Act 1993. Climate-driven problems are dealt by the Ministry of National Development (MND) with the support of research institutes. Although its activities are mainly for human-made disasters in Singapore, SCDF leads two of the five Working Group under AADMER and plays a key role in enhancing management capability of ASEAN Member States.

— Thailand

Thailand's DRM System was established based on the Disaster Prevention and Mitigation Act 2007 (B.E.2550) and the National Plan on Disaster Prevention and Mitigation 2015. The Disaster Prevention and Mitigation Act 2007 which entered into force on 6 November 2007 replaced the Civil Defense Act 1979 and Fire Defense Act 1999 (DDPM, 2015). This Act designated the top policy making body to be the National Disaster Prevention and Mitigation Committee (NDPMC), consisting of the ministries, agencies, and academia related to DRM. The chair of the committee is the Prime Minister, and the Secretariat is the Department of Disaster Prevention and Mitigation (DDPM). DDPM, originally established in 9 October 2002 following the Government Reform Act 2002, is authorized by the Act to be the central agency responsible for DRM. The Act also mandates DDPM to formulate the National Plan as it tries to harmonize and systematize DRM practices of all stakeholders at all levels.

The National Disaster Prevention and Mitigation Plan 2015 approved by NDPMC aims to minimize disaster risks, loss of lives and properties, and State property. The plan has three goals and four strategies:

Three Goals:
1. An effective DRM system is in place to tackle unprecedented emergencies.
2. Thai society is regarded as the Learning Community and capable of managing disaster risk.
3. Thai people are more safety minded, through which proper knowledge, risk awareness, safety culture and ultimately resilience are developed.

Four Strategies:
1. Disaster risk reduction oriented
2. Integrated emergency management
3. Effective recovery and resilience building
4. Strengthened international cooperation

The National Disaster Prevention and Mitigation Plan 2015 provides guideline, organization structure, and roles and procedures of each government agency related to DRM for all levels including national, provincial, district, and sub-district.

— Viet Nam

The Law on Natural Disaster Prevention and Control 2013 (No 33/2013/QH13) was approved in 19 June 2013, and became effective from 1 May 2014. It follows the National Strategy for Natural Disaster Prevention, Reduction, and Control 2007, and provides provisions to strengthen institutional and organizational structures of disaster-related agencies. The aim of the law includes the regulation of responsibilities, the coordination and support for the mechanisms of disaster-related agencies from central to local levels, and the outlining of international cooperation principles in DRR (UNDP, 2015).

There are also the Decree 66/2014/ND-CP (04 Jul 2014) detailing and guiding the implementation of some articles of the Law, Decree 94/2014/ND-CP (17 Oct 2014) on the establishment and management of a DRM fund, the Decree 44/QD-TTg (15 Aug 2014) detailing natural disaster risk level, the Decision 46 QD-TTg (15 Aug 2014) with regulations on forecasting, warning and natural disaster information communication, and the Joint Circular No. 43/2015/TTLT-BNNPTNT-BKHDT (23 Nov 2015) with statistical guidance to assess the damage caused by natural disasters. The Decision 367QD-TTg (16 Mar 2015) focuses on the establishment of Central Steering Committee for Natural Disaster Prevention and Control.

The Central Steering Committee for Natural Disaster Prevention and Control, headed by the Ministry of Agriculture and Rural Development (MARD) was established with an aim of coordinating ministries and agencies in organizing and directing natural disaster prevention, control, and recovery work and resource mobilization.

The Ministry of Planning and Investment is preparing the guiding Circular to engage DRR into the Socio-economic Development Plan (SEDP) 2016-2020. The DRR policies are noted in Output 2 of Outcome 3 of SEDP (UNDP, 2015).

Current Advances in DRR/DRM in ASEAN

The ASEAN Vision 2025 on Disaster Management was endorsed by the 3rd ASEAN Ministerial Meeting on Disaster Management (AMMDM) and the 4th Conference of the Parties (COP) to AADMER in December 2015 to address current and future disaster risks. The ASEAN Vision 2025 outlines the strategic direction for ASEAN in the next 10 years, further improving the implementation of AADMER by fostering a people-centered, people-oriented, financially sustainable, and networked approach by 2025. The vision also identified three strategic elements: (1) Institutionalization and Communications, (2) Finance and Resource Mobilization, and (3) Partnerships and Innovations.

Through the continued implementation of the AADMER Work Programmes, ASEAN contributes to the fulfillment of the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) and the Sustainable Development Goals. SFDRR was adopted at the 3rd UN World Conference in Sendai on March 18, 2015. SFDRR, the successor of the HFA 2005-2015, strongly emphasizes disaster risk management as opposed to disaster management, hence the focus on DRM and DRR in this roadmap. The seven global targets of the Sendai Framework are connected to many of the 17 Sustainable Development Goals.

— Drought

Despite considerable vulnerability to drought, there have been gradual progresses to reduce drought risk across the ASEAN regions. ASEAN countries have made efforts toward securing water availability and reducing drought impacts. A few ASEAN countries have prepared hazard and vulnerability maps at provincial and local levels, enabling support to decision-makers on resource allocations and management. ASEAN countries have made practical improvements in preparedness for severe drought conditions, including introducing new crop varieties and developing efficient agronomic practices.

Nonetheless, water allocation strategies are insufficiently developed between supply and demand sites. It is urgent to have integration of national, provincial, and local policies. In addition, robust drought monitoring system are still needed together with up-to-date evaluation frameworks at the national and sub-national levels, which will enable the integration of project-level risk information into policy making. Frameworks for integrated resource management are also necessary for long-term policy development.

— Flood/Inundation

Flood and inundation are caused by torrential rainfall or typhoon. Therefore, weather forecasting and observation is crucial for mitigation of flood disaster. Processed infrared and water vapor satellite image data and Doppler data obtained at near-real-time can be used to calculate probability of rain (Lagmay et al., 2017). Forecasting probability of rain is based on satellite images as well as an algorithm for cloud trajectory prediction using processing techniques based on the ForTraCC method (Vila et al., 2008). Locally-assembled automated weather stations (AWS) and automated rain gauges (ARG) have been installed in key areas in Philippine Astronomical Services Administration's (PAGASA) weather monitoring facilities (DOST-ASTI, 2011).

In terms of DRM, high-resolution hazard maps (1:5000 to 1:25,000 scale) based on similarly high-resolution topographic maps are very important (EXCIMAP, 2007). FiDAR can be used to generate high-resolution Digital Terrain Models (DTMs) with 1m horizontal and 0.2m vertical resolution of the lowland. If high-resolution DTMs are available, various hydrologic and hydrodynamics can be used to simulate channel flow and floodplain inundation maps.

Several numerical analysis work related to assessment of flood and inundation hazard has been carried out in Indonesia (Ishizuka et al., 2017), the Bago river basin, Myanmar (Zin and Win, 2015), Xedone river basin, and Lao PDR (Vilaysane et al., 2015). In addition, there is currently an operational web-based system which can display meteorological observation data, flood hazard maps, and rainfall prediction data (Lagmay et al., 2017).

— Landslide

According to the natural hazards level of severity by country, some of ASEAN region countries (e.g., Indonesia, Laos PDR, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam) are severely exposed to landslide disaster (World Bank 2005). Especially, the western and eastern area of java Island, Indonesia and the Philippines are recorded the most prevent hazard hotspot on landslide disaster in the ASEAN region (Yusuf and Francisco, 2009). Brunei has hilly areas are at risk of landslides and the highest percentage of population is exposed at landslide risk, followed by Philippines and Indonesia (DRMI 2010). Typhoons season in the Philippines during June to December occurs heavy rainfall. It can destabilize soils along mountain-slopes, resulting in landslides and mudslides that cause severe damage to nearby villages. Malaysia faces disaster risks from landslides and have experienced some man-made and man-induced landslide disasters mostly causing considerable damage to properties and loss of lives. According to the annual disaster profile in Vietnam, the damage of landslide disasters recorded 3% of total, and also Myanmar is exposed landslide disasters as a significant risk for regions on the western border due to hilly areas and extreme rainfall during monsoon/rainy season, which is during May to October.

— Typhoon

Remote sensing technology on board orbital satellite and GIS techniques are used in typhoon monitoring and forecasting (Goerss 2008; Kovordányi and Roy 2009). These technologies are also useful for data collection and post-disaster assessment (Lee et al., 2008; Kikuchi et al., 2009; Tsai et al., 2010). Remote sensing products related to typhoon include wind, waves, eyes of typhoons, precipitation, sea-level anomalies, and so on. Some of the products are used as input variables in typhoon forecast models.

Understanding the relationship between typhoon characteristics and large-scale circulations and climate change is potentially important for generating seasonal/annual outlook of typhoon risk and associated mid-term DRM. Extensive scientific research activity during the past 10 years enhanced our knowledge on environmental conditions modulating typhoons, e.g., impacts of ENSO (Camargo et al., 2007; Lyon and Camargo, 2009; Kim et al., 2011), connections to intraseasonal oscillation (Ko and Hsu, 2009; Kikuchi and Wang, 2010; Li and Zhou, 2013), changes of typhoon paths, and intensities under global warming (Webster et al., 2005; Emanuel, 2005; Knutson et al., 2010).

In the field of typhoon forecasting modeling, artificial neural network-based techniques have been introduced and are now being considered for use at meteorological offices (Ali et al. 2007; Kovordányi and Roy 2009). Using remote sensing images, this technique can be run under limited computing resources (e.g., personal computers) with relatively good accuracy.

Several modeling studies on storm surges has been performed for coastal regions in Myanmar (Jain et al., 2006; Fritz et al., 2011) and the Bay of Bengal (Murty, 1984; Dube et al., 1985; Sinha et al., 1986), although most of the modeling approaches are still under research (Dube et al., 2010). In addition, risk assessment and management models as well as decision support systems for typhoon disasters have been developed. These models utilize fuzzy theory, neural-network, or intelligent systems. Typhoon DRM/DRR can be also enhanced by use of the social media network in disseminating second-hand information and coordinating of relief efforts (Takahashi et al., 2015).

— Earthquake, Volcano, and Tsunami

Several advanced tools for Earthquake risk assessment including InaSAFE (Indonesia Scenario Assessment for Earthquake) and OpenQuake (Open Source Software for Seismic Hazards and Risk Assessment) were introduced during the ASEAN Capacity Building Forum on Risk Assessment held in March 2013. One widely used loss estimation model for earthquakes is HAZUS, which was developed by the US Federal Emergency Management Agency (FEMA) and the National Institute of Building Science (NIBS) (FEMA, 2003). HAZUS quantitatively estimates earthquake losses including the expected number of casualties based on engineering methods (FEMA, 2003). Recent studies incorporated human-related factors such as population characteristics in addition to the built environment to improve the predictive accuracy (e.g., Shapira et al., 2016).

The ASEAN Earthquake Model (AEM), a capacity-building programme, was initiated by three technical/research institutes: (1) Institute of Catastrophe Risk Management/Nanyang Technological University (ICRM/NTU), (2) Badan Meteorologi, Klimatologi, dan Geofisika (BMKG), and (3) Philippine Institute of Volcanology and Seismology (PHIVOLCS). ICRM is a research institute that undertakes multi-disciplinary research projects related to catastrophe risk. BMKG is an Indonesian government scientific organization performing tasks related to meteorology, climatology, and geophysics. PHIVOLCS is the Philippines' national institution mandated to formulate up-to-date and comprehensive disaster preparedness and risk reduction action plans for volcanic eruption, earthquake occurrences, and related geotectonic processes.

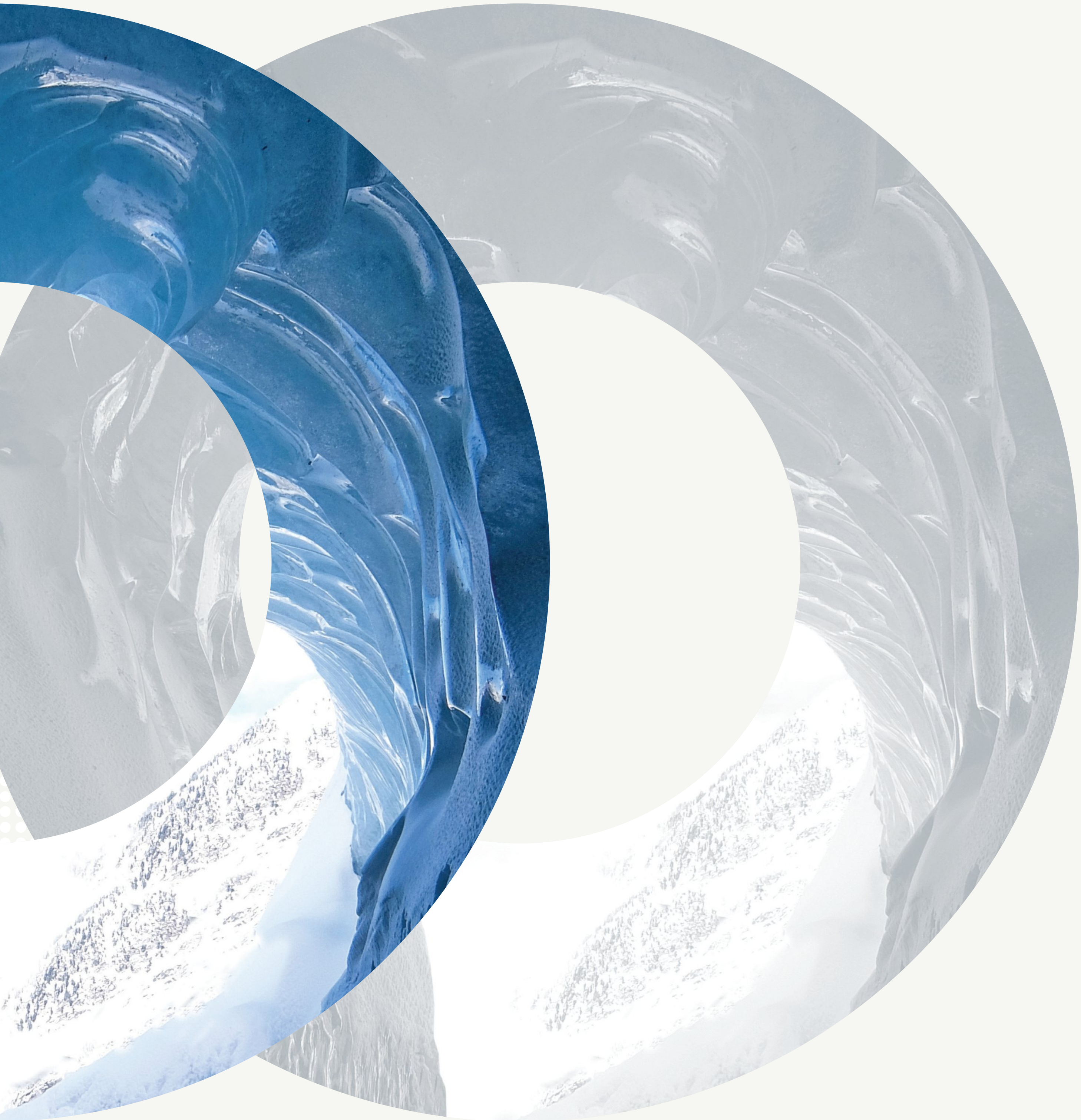
In Vietnam, there was very limited research on tsunamis before the Sumatra tsunami in 2014. After the event, significant research efforts were initiated in order to investigate historic tsunami events, characteristics of tsunamigenic earthquakes in the South China Sea, evaluating tsunami risk, and developing tsunami hazard maps.

To mitigate significant risk of disastrous tsunami event in the Philippines, PHIVOLCS, in association with the Advanced Science and Technology Institute (ASTI), devised and implemented a Tsunami Detection and Early Warning System (TeWS). TeWS consists of detection sensors, a data communication system using GSM data communication modules, data visualisation, interpretation, local tsunami emergency decision tools, and tsunami warning stations (Inazu et al., 2016). In addition, the core of an integrated, modern, and effective Tsunami Early Warning System in Indonesia was established based on German-Indonesian Tsunami Early Warning System (GITEWS) from 2005 to 2011. Indonesia now avails of one of the most modern Tsunami Early Warning Systems. On the basis of data from approximately 300 measuring stations a warning can be issued at a maximum of five minutes after an earthquake. These measuring stations include e.g. seismometers, GPS stations und coastal tide gauges. With the data gained from the sensors and using the most modern evaluation systems such as SeisComP3 which was developed by GFZ scientists for the analyses of earthquake data and a Tsunami simulation system in the Warning Centre it is possible to compile a comprehensive picture of the situation (Lauterjung et al., 2014).

Methods

Methodology to Derive DRR Options

Methodology to Prioritize DRR Options



Methods

In developing this research roadmap, we began by identifying a comprehensive list of research needs for each disaster type of interest. Then, through local consultations and surveys, we identified which of these research agenda items have already been done for the area of interest. Then the remaining research agenda items were prioritized and organized in order to develop the research roadmap suggested.

Methodology to Derive DRR Options

— Disaster Chain

The ASEAN region is exposed to various types of natural disasters. These include tropical cyclones, flood, drought, landslides, earthquakes, tsunami, volcanic eruption, forest-fires, and haze, etc. Rapid urbanization, socio-economic changes, and climate change are contributing to the increased impacts of natural disasters. Recent climate change and its uncertainties lead to greater natural disaster risk in ASEAN region countries. Therefore, there is a need to reduce this various uncertainty through science and technology and advanced DRM.

In terms of the process of the disaster formation and DRM, multi-hazards and disaster chains are both large issues. There are clearly differences between the two concepts of multi-hazards and disaster chains, although they look very similar and are often be used interchangeably (Shi, 2011). The multi-hazards concept is used throughout the SFDRR, but there is currently no clear definition provided by the United Nations Office for Disaster Risk Reduction (UNISDR). According to Shi (2011), the meaning of multi-hazards and disaster chains are defined as follows. The "multi-hazards" refers to a succession of hazards that always co-exist and occur at almost the same time and region, and "disaster chains" emphasize the causal relationships among those hazards that usually vary in temporal duration and spatial extension of influence. The general structure of disaster chains can be expressed as "Domino Effect" as follows in Eq. (1):

$$\mathrm{H} \rightarrow d_1 \rightarrow \cdots d_n \tag{1}$$

Where H = hazard, d_1 and d_n indicate the primary disaster and secondary disaster of the n^{th} order. Eq. (2) is a general structure of hazard chains (e.g., one trigger, multiple hazards) considering parallel disasters with a ripple effect.

$$\mathrm{N} \rightarrow H_1 \cdots H_m, (H_1 \rightarrow d_1 \rightarrow \cdots d_n,\ H_m \rightarrow d_{m1} \rightarrow \cdots d_{mn}) \tag{2}$$

Where indicates the natural dynamic process of earth $H_1, \cdots, H_m$ system, means primary hazards, $d_1, d_n, d_{m1}, \cdots, d_{mn}$ and means secondary disasters. The disaster chain was created to derive related components to natural disaster research. It shows causal relationships among the hazards that usually vary in temporal duration and spatial extension of influence.

Figure 4 shows an example of the disaster chain on earthquake-tsunami in Japan in 2011. At that time, the 9.0 magnitude earthquake at 14:46 on 11 March 2011 caused a massive tsunami that devastated the shores of Japan's Honshu island. The earthquake caused waves of up to 14 meters tall and some traveled 10km inland. Due to the tsunami, earthquake, and an ensuing nuclear disaster, the Japanese economy faced a great economic damage. The loss of two nuclear power plants led to the Tokyo region facing the summer peak energy demand with around 20% loss of capacity. Some airports were shut down; food, water, and fuel were in short supply; and there were several secondary disasters driven by socio-economic and environmental effects.

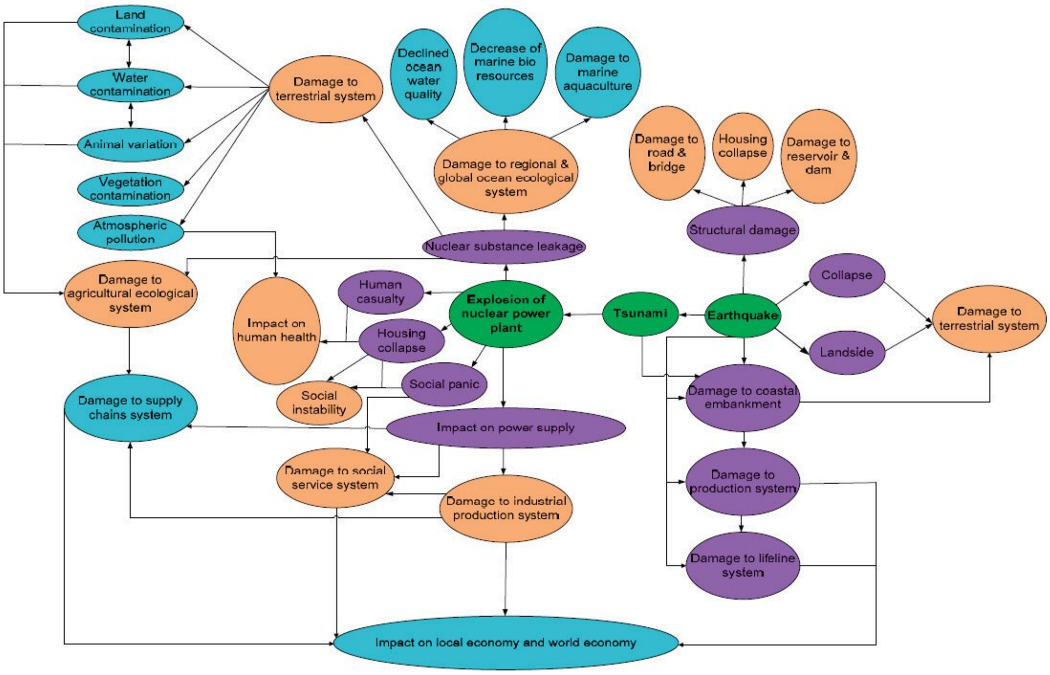


Figure 4. An example of the disaster chain on earthquake-tsunami in Japan in 2011 (Shi, 2011)

— Disaster Risk Reduction Model

There have been enormous efforts by ASEAN member states to commit to the HFA through AADMER, the proactive regional framework for cooperation, coordination, technical assistance and resource mobilization in all aspects of DRM. Successfully implemented programmes and activities of the AADMER Work Programmes enabled them to envisage the fulfillment of the DRR and DRM Goals.

Based on the DRM framework, HFA 2005-2015 Priorities for action, and SFDRR 2015-2030 Priorities for action, we have categorized the Disaster Research Agenda (DRA) into five steps below:

- Step I: Data collection
- Step II: Risk analysis
- Step III: Understanding disaster risk
- Step IV: Developing system for disaster risk management
- Step V: Strengthening and enhancing disaster risk management plans

- Horizontal: Understanding, strengthening, investing and enhancing for disaster risk reduction
- Vertical: Integration, coordination, cooperation, construction, and communication for actions in community level and stakeholders

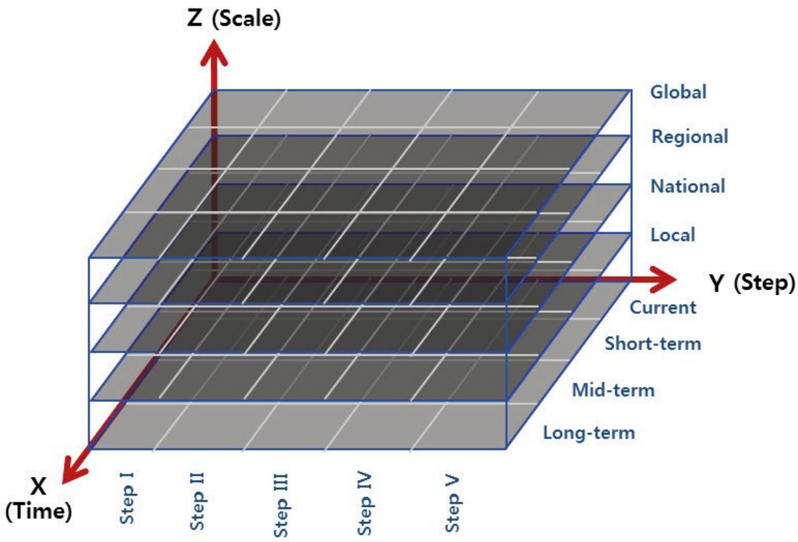


Figure 5. DRM model for research roadmap

— Research Matrix

Research matrices for each disaster type were developed under an assumption of no existing DRM research. Under this condition, **the first step [data collection]** for establishing a risk management framework is to collect relevant datasets. Meteorological data are essential with sufficient data length and quality. Geophysical and socioeconomic information, such as land-use data, population density and growth rates, and municipal and industrial information, enables the estimation of exposure and vulnerability to disasters. The scenario-based projections of global climate models (GCM) allow the measurement of future risk and preparation of adaptation strategies to cope with anthropogenic climate change impacts. **The second step [risk analysis]** would be to analyze these data sets to quantify historical hazards, exposure, and vulnerability to each disaster type.

Then, **the third step [understanding disaster risk]**, by mapping the quantified disaster risks, it will be possible to identify disaster-prone areas. These risk assessments provide fundamental information for establishing disaster monitoring systems. Then strategies, policies, laws, and regulations can be developed and updated using the monitoring systems and the archived records. This will inherently strengthen the DRM plans.

In **the fourth step [developing system for DRM]** the mid-term and the long-term research items can be aimed toward prediction-based risk management. Reliable climatic predictions extend the time to have preparedness for upcoming disasters; however, uncertainty in the forecasts should be carefully addressed in decision-making processes. Both observation- and forecast-based DRMs are essential in the mid-term and long-term frameworks together with uncertainty assessment. The short-term management based on existing information should evolve over time as data are accumulated, since maintenance of management framework is a key task to provide consistent effectiveness. And in **the fifth step [strengthening and enhancing DRM plans]**, new meteorological data may capture unprecedented hydro-climatological shifts. A real-time forecasting and early warning system will significantly contribute to managing disaster risks in a proactive manner. For governance of risk management framework, upgrading policies and education programs are always necessary. Without policy governance, scientific and technological advances cannot be sufficiently embedded in the risk management framework.

We developed a disaster chain and research matrix for each disaster type in the research roadmap. These disaster chains and research matrices were peer-reviewed by experts for each type of disaster.

Methodology to Prioritize DRR Options

In the context explained above, specific research items can be fit into ideal research matrices for each disaster types. However, countries may vary in their current status in these matrices. For the research roadmap, each research agenda item was prioritized different for each country and disaster type dependent on the already completed agenda items, variations in vulnerability, and national political priorities. This research roadmap's prioritization was based on literature reviews, questionnaire surveys, and in-country meetings with stakeholders.

The questionnaire survey was developed to investigate the key themes of disaster-related research in the past ten years, determine the knowledge library composition, obtain information on current and emerging disaster-related issues, and eventually develop collaborative and multidisciplinary research programs that will address current and emerging issues as well as longer term concerns in DRM.

The detailed survey questionnaires were developed for the most affecting four hydrological disaster types of flood, landslide, typhoon, and drought. In the first part of the survey (hereafter referred to as Survey I), each research agendum of the research matrix for each disaster type introduced in General Methodology Section is asked to be labeled as one of the following: "already done", "should be done in the short-term", "should be done in the long-term", and "unnecessary/not relevant." Respondents may also add any missing research agenda to the research matrix through the five steps.

The second part of the survey (hereafter referred to as Survey II) served to prioritize the research agenda that are previously labeled as "should be done in the short-term" during the first part of the survey. Respondents ranked these research agenda for each of the five steps in the matrices.

For earthquake, volcano, and tsunamis, the survey allowed respondents to provide their own ideas of DRR options for each of the five steps of the DRR framework. Existing knowledge products or tools available for global/regional usage regarding these disaster types were provided for references. Respondents also ranked the research agenda that they provided and labeled as "should be done in the short-term."

In order to prioritize research options for each disaster type and for each country based on a survey method, it is appropriate to use a well-established consensus method such as the Delphi Technique. The Delphi technique was originally developed by Dalkey and Helmer (1963) at Rand Corporation, and is widely used for forecasting, needs assessment, and decision making through transforming opinions of experts into consensus (Hasson et al., 2000; Powell, 2003). However, the traditional Delphi technique could not be used here because many responses from government and research organizations are not individual responses but are representative of the organization as a whole. Many governmental and research organizations prefer providing their responses after sufficient internal discussions. Instead of the traditional Delphi Technique requiring several times of feedback as a multistage process, a relatively simple questionnaire survey method with a single stage was used.

However, the concept of the Delphi Technique, which is forming consensus through communication between experts, is still reflected in this roadmap. Through the Kick-off Workshop held in March 30-31 in Busan, Republic of Korea for "understanding the current research and policies on disaster management in the ASEAN region"; the Regional Symposium held in February 9-10 in Jakarta, Indonesia for "promoting and supporting scientific and technical research that will inform disaster management practice and policy"; and country visits conducted over the span of three months, policy-makers and practitioners of national DRM offices and researchers in the ASEAN region met and discussed current DRM issues, future research needs, and many DRR options.

Each survey questionnaire for the four hydrological disaster types as well as the research matrices with DRR options was prepared by experts of the project team according to their respective domains of expertise. The questionnaires and research matrices were peer-reviewed by two additional experts respectively, in order to go through an experts-group communication process once again.

Final survey questionnaires were then developed online for increased accessibility (http://survey.apcc21.org:8089/). The questionnaire surveys were promoted to related key institutions and government agencies through two ways: (1) country-visits and (2) dissemination of survey questionnaire or the link to the on-line version by e-mail.

The project team visited a total of 33 institutions and government agencies from April to June, 2017, and 178 more experts were invited to complete the survey online. ASEAN Secretariat also distributed the survey link to relevant experts in DRM community. Each visited organization mostly provided their agreed responses for each of the related disaster types, while respondents invited by e-mail tended to provide their individual opinions.

Figure 6. On-line survey questionnaire: the start page.

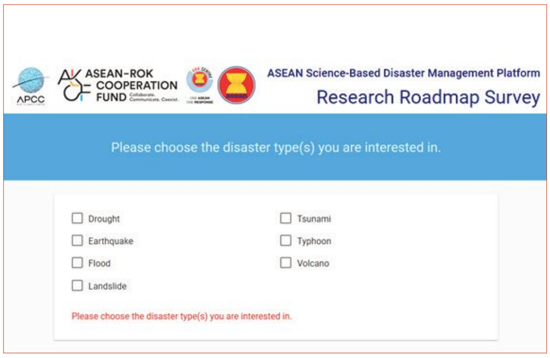


Figure 7. On-line survey questionnaire: each survey questionnaire for the selected disaster type follows.

Intensive literature review and the survey responses were used to develop the short-term and long-term research roadmaps. For the short-term research roadmap on the regional scale for DRM issues currently faced, the short-term research needs that survey respondents provided were prioritized according to the rules below:

1) Remain short-term research needs with high priorities (e.g. top 5 from each respondent);
2) Sort selected short-term research needs based on their popularity (from all respondents);
3) Select and list short-term research needs with high popularity (e.g., count > 3)

Through this process, the most important and urgent short-term research topics could be refined. For the long-term research roadmap on the regional scale for determining future research, a similar approach was used. Long-term research options that appeared consistent between respondents were selected and provided.

More detailed explanations and analyses of survey responses were given for country-based research roadmaps. For disaster types of Earthquake and Tsunami, a research matrix only based on survey responses was given without prioritization of the short-term research agenda as the survey questionnaire was developed to only get suggestions from respondents for these disaster types. We are not able to include the research matrix for Volcano due to the lack of respondents with valid answers.

Regional
Research Roadmap

Drought

Flood/Inundation

Landslide

Typhoon

Earthquake, Volcano, and Tsunami

Regional Research Roadmap

An extreme climate event can affect more than one country simultaneously. Activities for DRR in one country may also affect neighboring states. For example, water resource management practices in one country can influence water quality as well as quantity in an adjacent country. For this reason, disaster management research roadmap on the regional scale is provided in addition to the country-based research roadmap.

Drought

— Drought Chain

The drought chain begins from deficient precipitation, and its impacts slowly and widely expand to human society through natural systems. Through the chain effects, drought is classified into four major categories: meteorological, agricultural, hydrological, and socioeconomic.

The lack of precipitation (meteorological drought) is followed by declining soil moisture; thereby, the productivity of rain-fed crops is diminished (agricultural drought). In severe cases, long-lasting dry conditions could lead to desertification and forest degradation. When precipitation deficiency continues, river flows and wetlands are significantly reduced (hydrological drought). In response, changes in the habitats and ecosystems are observed due to imbalance across the hydrologic systems. The declining streamflow limits water flows and storages in infrastructures for water supply (e.g., canals, reservoirs, and pipe networks). When water supply cannot satisfy societal water demands, human livelihoods and social cohesion are weakened by water and food insecurity (socioeconomic drought).

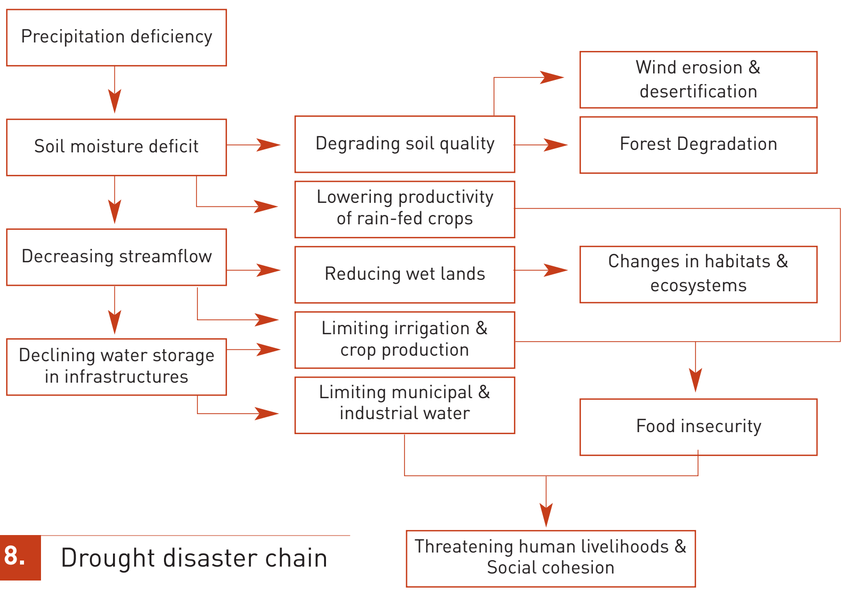


Figure 8. Drought disaster chain

— Drought Regional Roadmap

Figure 9 shows the research agenda for drought risk management necessary under no exiting framework. For drought risk management in a proactive manner, it is essential to have comprehensive drought monitoring and early warning systems, risk and impact assessments, and preparedness and emergency plans (Wilhite et al., 2014). Without these primary components, government policies would continue to be in the "crisis management" mode, which has limited effectiveness on reducing drought risks. IPCC (2012) highlighted that countries without such components are likely to have deficient institutional flexibility and thus high vulnerability. The research matrix in Figure 9 includes fundamental components for drought risk reduction.

DRR Options: Risk Management; Risk Assessment; Risk Analysis

Drought	Current and Short-term (Present ~ 2020)	Mid-term (2021~2025)	Long-term (2026~2030)
Step I Data collection	• Meteorological data • Geophysical and hydrological data • Socioeconomic data • Climate change scenarios • Projections of socioeconomic conditi ons	• Updating meteorological data and i mproving data quality • Expanding data categories related t o drought (e.g. agronomic data) • Updating socioeconomic and climat e change scenarios	• Updating database and advancin g quality control procedure • Real-time collection of meteorolo gical and hydrological data and fo recasts
Step II Risk analysis	• Analysis of drought occurrence and s everity • Assessing spatial extent of droughts • Assessing inventory resources and i dentify groups at risk	• Updating spatial-temporal drought analyses • Assessing further impacts of droug ht on societies • Assessing social resilience to droug ht impacts	• Establishing forecast-based risk a nalysis framework
Step II Understanding drought risk	• Mapping drought risks in terms of ha zard, exposure, and vulnerability • Assessing climate change impacts o n drought risk • Assessing risk of changing socioeco nomic conditions	• Developing mitigation plans under c hanging conditions • Finding and assessing adaptation s trategies	• Assessing drought hazard and vul nerability under forecasted climati c conditions
Step IV Developing Sy stem for disast ers risk manag ement	• Developing drought monitoring syste m • Archiving past drought events and th eir consequences	• Finding predictors of drought for ea rly warning • Improving social communication sy stem (Mass media, Tele-communic ation)	• Developing real-time forecasting and early warning system • Developing Integrated multi-hazar d detection system
Step V Strengthening and enhancing disasters risk management p lan	• Review on existing strategies, policy, plans, laws and regulations • Developing drought risk education a nd training program • Developing policies for emergency re sponse and relief • Establishing local drought policy fra mework	• Improving governance and stakehol ders' cooperation • Developing regional drought policy framework • Developing risk mitigation and contr ol plan • Identifying and fill institutional gaps	• Developing and publicizing nation al drought policy framework • Evaluating and revising drought mitigation plans periodically

Figure 9. Ideal research matrix for drought risk management

The results of Survey I for drought are summarized in Figure 10. The 14 respondents of Survey I represented Malaysia, Lao PDR, Vietnam, Thailand, New Zealand, and Taiwan. 11 respondents among the 13 indicated expertise related to natural disasters and are working in institutions in the drought-prone ASEAN countries. The responses to the items in step I show that current data collection is insufficient to assess drought risk in the ASEAN countries. This insufficient data availability might lead to limited drought analysis and assessment (i.e., steps II and III). The "already done" responses to the items in steps II and III were only 12.5% and 3.6%, respectively. Improving data availability is likely an urgent research topic for drought risk management. Interestingly, the "already done" responses to the items in step IV were higher than steps II and III. It implies that the current meteorological gauging networks might be deemed useful for drought monitoring, though they have inadequate data lengths and spatial coverages. The monitoring networks in the ASEAN region may provide precipitation anomaly information in a timely manner. However, limited spatial and temporal coverages of monitoring networks can lead to unreliable drought analyses and assessments. Expanding the coverage of the monitoring networks may be a high-priority research topic.

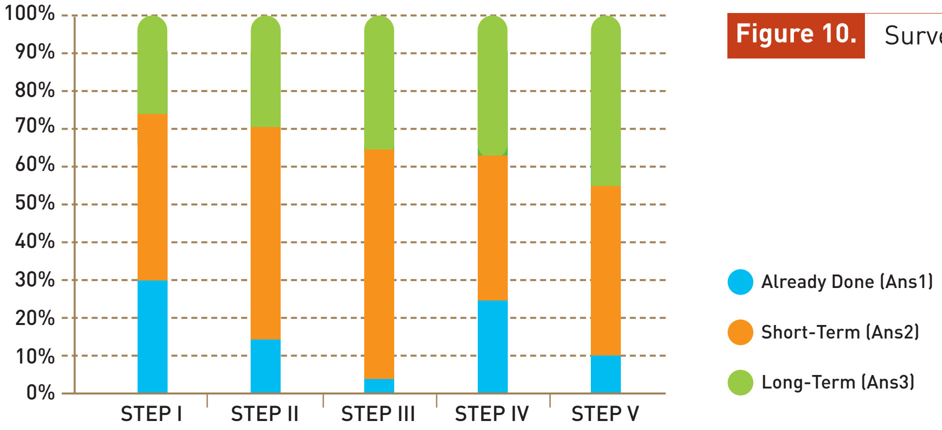


Figure 10. Survey I results for drought

High-priority short-term research topics for step I were "Updating meteorological data and improving data quality", "Expanding data categories related to drought", "Updating database and advancing quality control techniques", and "Collecting projections of socioeconomic conditions", indicating that they are all related to improving data availability and quality. The items for risk analysis and assessment in steps II and III were mainly selected as short-term topics (57% and 62% respectively). The research agenda in steps II and III should follow, once data availability and quality are upgraded. Twelve respondents selected the item "Assessing resource inventory and identify groups at risk" in the step II as a short-term agendum, implying that more efforts should be directed toward reliable estimation of exposure to severe drought conditions. In addition, ten respondents selected the item "Updating spatial-temporal drought analyses" as a short-term item. Perhaps, current drought characterization could be outdated or unreliable for risk management.

The portion of long-term research agenda increases with the step number. The respondents tend to select developing systems and strengthening management plans as agenda that should be accomplished within a long-term, while data collection and analyses were their short-term interests. Nine respondents selected the forecast-based risk assessment as a long-term agendum, implying that current drought forecast techniques may be insufficient to be utilized in the management framework. Developing multi-hazard detection systems was chosen as the top long-term research agendum in step IV. Multifaceted management is important when multiple types of natural disasters need to be considered together. For example, avoiding flood-prone regions may result in more exposure to severe droughts. The survey results show that this multi-dimensional management is a long-term interest of the respondents. Multi-hazard risk analyses and assessment may require multidisciplinary analyses in which collaborations between experts in different fields play a crucial role. For step V, eight respondents selected "Establishing regional drought policy framework" as the top long-term agendum. In doing so, it is necessary to link between the national and the local management frameworks within a long-term.

Table 10 lists the short-term high-priority items selected in Survey II for each step. As expected, the items for upgrading data collection and drought risk analyses are in high priority for step I. The respondents would recognize that maintenance of gauging networks is essential for drought monitoring and early warning. The socioeconomic conditions can rapidly change, and thus alter exposure and vulnerability to drought conditions. Importantly, the chain effects of drought are not limited on water resources allocation, but energy generations (Shadman et al., 2017). Sensitivity of power generation on water availability would be an important factor to evaluate vulnerability of a society to severe and extreme droughts.

The high-priority agenda for step II was reliable estimation of exposure to droughts and drought characterization. They are fundamental components for drought risk and vulnerability assessment in step III. Although drought risk and vulnerability maps are currently available for several ASEAN countries (e.g., Cambodia web-based maps), they should be routinely updated and improved using new data and information. Developing drought monitoring systems is essential for early warning. Finding predictors of drought is also chosen as a short-term agendum, indicating necessity of prediction-based risk management within a long-term. For strengthening and enhancing the management plans, the reviews on current the plans and education programs were chosen as high-priority agenda, emphasizing the governance of the national, regional, and local frameworks for effective risk management. The results of Survey II emphasize that drought monitoring and prediction technology should be embedded in the national framework for scientific risk assessment and early warning.

Table 10. Short-term high-priority research agenda for drought risk management

Steps	Research Agenda
Step I Data collection	• Updating meteorological data and improving data quality • Collecting projections of socioeconomic conditions
Step II Risk analysis	• Assessing resource inventory and identify groups at risk • Analysis of drought occurrence and severity
Step III Understanding disaster risk	• Mapping drought risks in terms of hazard, exposure, and vulnerability • Assessing climate change impacts on drought risk
Step IV Developing system for disaster risk management	• Developing drought monitoring system • Finding predictors of drought for early warning
Step V Strengthening and enhancing disaster risk management plan	• Review on existing strategies, policy, plans, laws and regulations • Developing drought risk education and training program

Table 11 summarizes the long-term high-priority research agenda selected based on selection frequency in the Survey I. For data collection (step I), gathering socioeconomic data and updating climate change scenarios were chosen. Two major drivers of increasing drought risks are population growth and global warming that can significantly alter water supply and demand trends. Data related to climatic and socioeconomic changes can be basis to prepare for unprecedented extreme droughts. For step II, the forecast-based risk analysis framework was selected. The SSTs and the data-driven models can be employed to predict future drought conditions. Of course, uncertainty should be considered in the framework. Assessing social resilience to drought impacts was another long-term agendum. Evaluating connectivity between water supply and demand sectors would be a key for resilience assessment. The agenda selected for step III is to embed the changing climate and socioeconomic conditions in risk analysis and assessment. As mentioned earlier, the multi-hazard detection system was selected for step IV as an important research topic in a long-term. Research on social communication systems will improve distribution of disaster information. Regional drought policy that connects national and local level frameworks will enhance the governance of the management framework. Drought mitigation plans need to be updated as well as reviews on policy and regulations.

Table 11. Long-term high-priority research agenda for drought risk management

Steps	Research Agenda
Step I Data collection	• Collecting socioeconomic data • Updating socioeconomic and climate change scenarios
Step II Risk analysis	• Establishing forecast-based risk analysis framework • Assessing social resilience to drought impacts
Step III Understanding disaster risk	• Assessing risk of changing socioeconomic conditions • Developing mitigation and adaptation plans under changing conditions
Step IV Developing system for DRM	• Developing integrated multi-hazard detection systems • Improving social communication system (mass media, Tele-communication)
Step V Strengthening and enhancing DRM plan	• Developing regional drought policy framework • Evaluating and revising drought mitigation plans periodically

The following is a summary of scientific research about drought monitoring, prediction, and assessment, and policy improvement for the past two decades, which are related to the high-priority agenda in the research roadmap. This will be beneficial when specifying the research agenda.

For monitoring purposes, various drought indices can be used instead of the simple precipitation anomaly. The Standardized Precipitation Index (SPI; McKee et al., 1993, 1995) and the PDSI (Palmer, 1965), for instance, are conventional drought indices that have been commonly employed in the drought monitoring system (e.g., the U.S. Drought Portal at https://www.drought.gov/drought). Other indices that can be employed in the drought monitoring systems are the Effective Precipitation (EP; Byun and Wilhite, 1999), the Soil Moisture Deficit Index (SMDI; Narasimhan and Srinivasan, 2005), the Standard Runoff Index (SRI; Shukla and Wood, 2008) among many variations. Data lengths and quality directly affect reliability of the drought indices (Dai, 2013; Mishra and Singh, 2010). At minimum, quality precipitation data need to be available with a sufficient length. Temporal and spatial resolutions of the meteorological datasets determine capacity of drought monitoring systems. Because several global datasets are readily available online (e.g., the Climatic Research Unit Data at https://crudata.uea.ac.uk/cru/data/hrg/), historical drought mapping and assessment are currently possible across the ASEAN region at a relatively high resolution, although local meteorological monitoring seems insufficient yet. To do this, institutional capacity is required for handling the global datasets.

One recent research direction is to integrate multiple variables in drought indices. This research stem is mainly to consider multifaceted aspects of drought phenomena. Vicente-Serrano et al. (2010), for example, proposed the Standardized Precipitation-Evapotranspiration Index (SPEI) to take into account the atmospheric moisture demand together with precipitation. Reconnaissance Drought Index (RDI; Tskiris and Vangelis, 2005) was proposed in the same context. Hao and AghaKouchak (2013) proposed the multivariate standardized drought index that uses joint probability distribution between precipitation and soil moisture. These drought indices enabled to integrate multiple aspects of water supply and demand into drought characterization. Another important research direction is the remote-sensing based drought monitoring. In the past decade, new remote sensing datasets have become available for precipitation, snow, soil moisture, surface temperatures, evapotranspiration, and vegetation (e.g., NASA, 2010; Wardlow et al., 2012). The remote-sensing estimates enabled near real-time drought monitoring with enhanced spatial resolutions and high data consistency (AghaKouchak et al., 2015). The Evaporative Stress Index (ESI; Anderson et al., 2007) is a prominent example that detects evaporative stress using satellite-based estimates of evapotranspiration. Drought monitoring systems can be improved with on-going advances in remote-sensing technology.

The drought indices can be applied to modeling and prediction studies. Many approaches for drought prediction are dependent on the time series of observed drought indices. Mishra and Singh (2011) summarized general approaches to prediction and characterization of droughts. Conventional prediction techniques are the time series analysis and the machine learning such as the artificial neural network and the support vector machine. The assumption underlying these models is that observed natural variations can explain the periodic nature of drought occurrences. However, the data-driven approaches may not capture unprecedented periodic behaviors of droughts under global warming in spite of their usefulness. Global climate models, albeit they have limitations too, may become alternative to predicting unprecedented drought conditions (e.g., Steinemann, 2006).

In addition, recent scientific literature highlighted the teleconnection between meteorological extremes in the Southeastern Asia and the ENSO (e.g., Dai and Zhao, 2016; Zhang et al., 2016; Mishra and Singh, 2011); thus, monitoring SSTs may become a key feature in early-warning systems. In other words, SSTs can be a good predictor of droughts for the ASEAN region. Thirumalai et al. (2016) argued that ENSO-related effects have been significant for March-May when ENSO events decay, suggesting predictability of post-Nino Aprils to prepare for adverse effects of water and heat stresses. Nonetheless, due to significant spatial and temporal variations in ENSO events, uncertainty of the ENSO effects needs to be considered together in decision-makings beyond "prediction and control" policies (Räsänen et al., 2016).

Scientific and technological advances in drought monitoring and prediction do not guarantee successful risk reduction in practice. It is well-documented that institutional failure is a root cause of underdevelopment and susceptibility to disasters (Ahrens and Rudolph, 2006). Ahrens and Rudolgph (2006) suggested that key features to improve the governance are accountability, participation, predictability, and transparency in policy development. Howes (2014) emphasized that interagency communications can promote networked governance for DRM. Individuals with low risk perception are less likely to prepare for natural hazards (Ruin et al., 2007; Hung et al., 2007); hence, governments and institutions should play a main role in educating DRM to public. A comprehensive review of Wachinger et al. (2013) suggested that personal experience of natural hazards are the most substantial factor affecting risk perception, emphasizing importance of public participation on awareness of potential disasters. Under water stress, it is especially important to transfer knowledge for strategic agricultural management to local stakeholders so as to sustain the agriculture-dependent economy in the Southeast Asia. Scientific communities have showed that agronomic, environmental, and management measures are all necessary to cope with increasing drought risk (e.g., Haefele et al., 2016); however, transferring knowledge at a research project level to local and regional stakeholders is challenging and thus needs further studies. New educational strategies will play a crucial role in promoting public awareness and preparedness.

Another recent accomplishment in drought-related studies was identification of global drought risk under global warming. Those studies include drought risk assessment in ASEAN countries that can be beneficial for the long-term research agenda. Dai (2011), for instance, reviewed literature on drought during the last millennium with an assessment on global aridity changes for 1950-2008, highlighting that recent warming in the 21st century is likely attributed to the drying climate in many regions including

Southeast Asia. Dai (2011) emphasized that future efforts toward drought prediction would depend on predictability of tropical SSTs. Dai (2013) updated his drought risk assessment using new climate projections of the IPCC, and provided the same conclusion of increasing drought risk over the world. On the contrary, Sheffield et al. (2012) found little change in global drought risk from trends in historical PDSI during 1950-2008. However, this contradictory study has been challenged by following studies such as Cook et al. (2015) and Dai and Zhao (2016), which found increasing global drought risk with higher quality datasets than Sheffield et al. (2012). An important lesson from these studies is that anthropogenic greenhouse gas emissions are likely to result in more severe and extreme drought events, although natural climate variations still play a major role in drought occurrence. Temporal evolution and oscillation of SSTs seem to be two principal components that explain spatio-temporal variations of historical droughts, implying that both human-made and natural effects contribute to drought occurrence and severity (Dai and Zhao, 2016). Several recent studies showed that extreme climatological events in the Southeastern Asia have been closely related to ENSO (e.g., Thirumalai, 2017; Zhang et al., 2016).

— Conclusion and Future Plan

Drought impacts can be nonstructural and thus are often unnoticeable unlike other natural disasters. Therefore, proactive measures are essential for effective mitigation of drought impacts, although structural measures such as increasing capacity of infrastructures still play a role in securing water supply. Proactive soft measures may include improving climate forecasts, developing education programs for water conservation, enhancing connectivity of water supply between demand sectors, and building capacity of stakeholders for drought planning and awareness. The research roadmap proposed here is to reduce exposure and vulnerability to drought and to foster social resilience by improving data availability and analysis, developing early warning and monitoring systems, and strengthening governance of the risk management framework. Several emerging studies related to the research agenda were summarized here together. These will be helpful to mitigate devastating impacts spreading through the drought chain.

For implementation of research projects based on the proposed roadmap, capacity building will be necessary for the least developed countries having limited human resources. It may require expensive efforts for funding and organizing the programs and for collaborations. However, such efforts will be undoubtedly valuable. Drought has resulted in millions of casualties in underdeveloped countries. In addition, how to link between the research and decision-making is a remaining important agendum. Nowadays, decision-makers in the world confront overflow of information, though overall data availability and quality seem to be not sufficient yet in the ASEAN countries. As data and studies are accumulated in the ASEAN region, how to extract core information from large data sources will become an important issue as well as visualization of the core information.

Flood/Inundation

— Flood/Inundation Chain

Climate change is increasing sea surface temperatures, which in turn increases the frequency and intensity of tropical cyclones (Webster et al., 2005). From this, it can be followed that the intensity and frequency of floods will be increased in the world, as well as in the ASEAN region, as extreme rainfall events are one of the trigger parameters for flood and inundation.

Extreme rainfall causes floods, which do not only trigger general damages. Figure 11 shows causal relationships among the hazards related to flood disasters. These hazards greatly vary temporally and spatially. For instance, if extreme rainfall exceeds a certain level of rainfall intensity, rivers can overflow. The overflow inundates residential areas and farmlands, and can erode the river banks, potentially fully destroying the river banks. These flood impacts can either occur sequentially or concurrently as summarized in Figure 11.

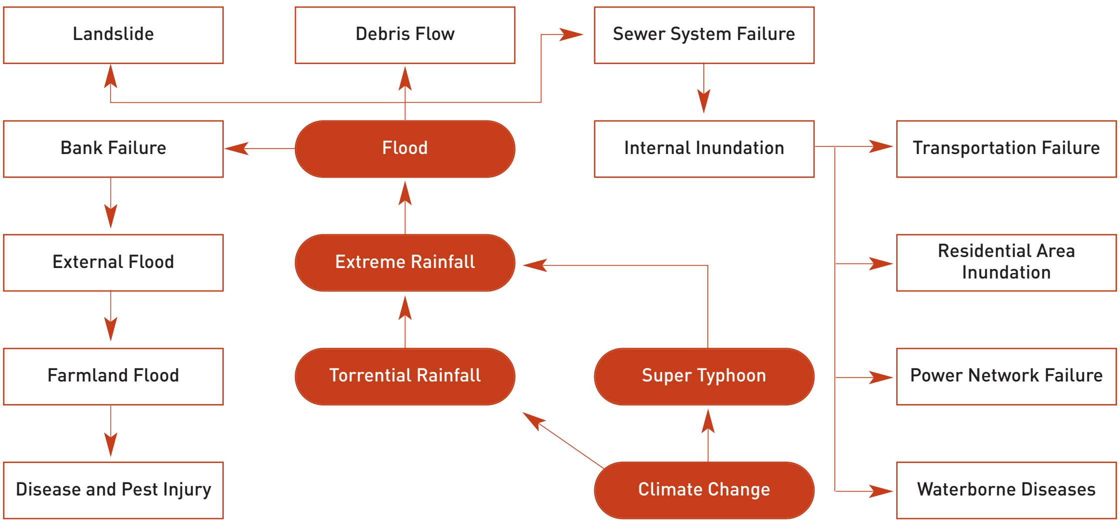
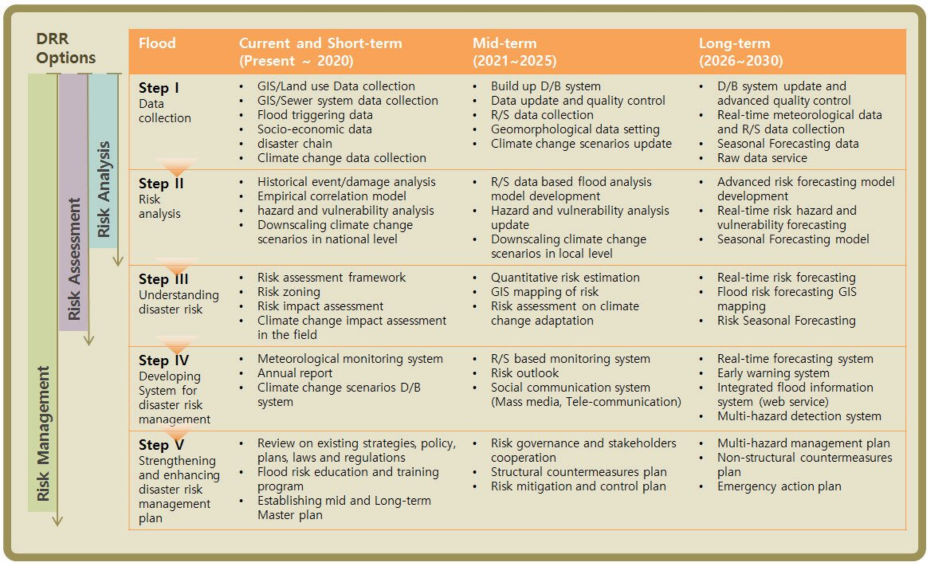


Figure 11. Flood Disaster Chain

— Flood/Inundation Regional Roadmap

Figure 12 shows the research agenda matrix developed for floods



Flood	Current and Short-term (Present ~ 2020)	Mid-term (2021~2025)	Long-term (2026~2030)
Step I Data collection	• GIS/Land use Data collection • GIS/Sewer system data collection • Flood triggering data • Socio-economic data • disaster chain • Climate change data collection	• Build up D/B system • Data update and quality control • R/S data collection • Geomorphological data setting • Climate change scenarios update	• D/B system update and advanced quality control • Real-time meteorological data and R/S data collection • Seasonal Forecasting data • Raw data service
Step II Risk analysis	• Historical event/damage analysis • Empirical correlation model • hazard and vulnerability analysis • Downscaling climate change scenarios in national level	• R/S data based flood analysis model development • Hazard and vulnerability analysis update • Downscaling climate change scenarios in local level	• Advanced risk forecasting model development • Real-time risk hazard and vulnerability forecasting • Seasonal Forecasting model
Step III Understanding disaster risk	• Risk assessment framework • Risk zoning • Risk impact assessment • Climate change impact assessment in the field	• Quantitative risk estimation • GIS mapping of risk • Risk assessment on climate change adaptation	• Real-time risk forecasting • Flood risk forecasting GIS mapping • Risk Seasonal Forecasting
Step IV Developing System for disaster risk management	• Meteorological monitoring system • Annual report • Climate change scenarios D/B system	• R/S based monitoring system • Risk outlook • Social communication system (Mass media, Tele-communication)	• Real-time forecasting system • Early warning system • Integrated flood information system (web service) • Multi-hazard detection system
Step V Strengthening and enhancing disaster risk management plan	• Review on existing strategies, policy, plans, laws and regulations • Flood risk education and training program • Establishing mid and Long-term Master plan	• Risk governance and stakeholders cooperation • Structural countermeasures plan • Risk mitigation and control plan	• Multi-hazard management plan • Non-structural countermeasures plan • Emergency action plan

Figure12. Flood Research Agenda Matrix

For flood/Inundation, 22 survey responses were received from government offices (14), an international organization (1), non-governmental organizations (3), research organizations (2), and universities (3). The "Unnecessary" answers were ignored in the statistical analysis. Figure 13 displays a summary of flood survey results, which are the average of the survey results.

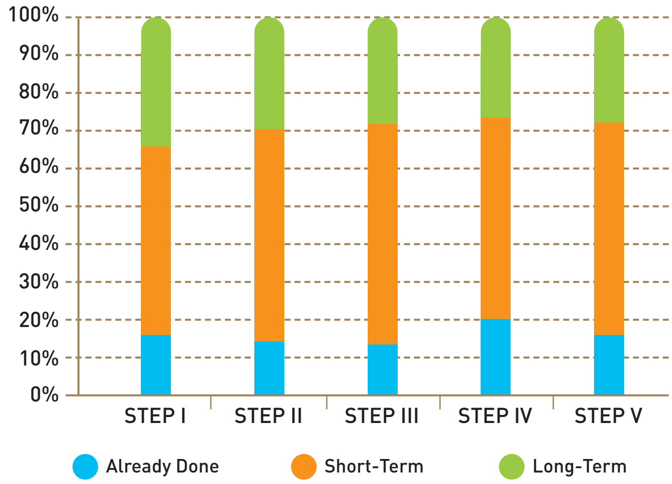


Figure13. Percentage of flood survey response

In step I (data collection), the items prioritized to be "short-term" are related to the current available technical issues, while the items prioritized to be "long-term" can be collected by using cutting-edge techniques. In step II (risk analysis), the "short-term" items are related to hazard and vulnerability analysis, which can estimate the current environmental status. The step II "long-term" items include downscaled climate scenario data. step III and IV (understanding disaster risk and developing system for DRM, respectively) seem to be the most urgent, as most of the identified items are relatively in the initial stages of research topics compared with the long-term priotiy items. step V (strengthening and enhancing DRM plan) results were interesting as conventional DRM plans such as structural and non-structural countermeasures were not selected as short-term priorities. Instead, risk training and governance for communities combined with reviewing political plans were selected to be the short-term priority items in step V.

Based on the result of survey part II (prioritization), the items to be implemented in the short-term in the ASEAN region are listed in Table 12.

Table 12. Short-term high-priority research agenda for flood risk management

Steps	Research Agenda
Step I Data collection	• Flood triggering data • In-situ test data • Disaster chain • Data update and quality control • R/S data collection • Geomorphological data setting • Climate change scenarios update
Step II Risk analysis	• Historical event/damage analysis • Empirical correlation model • Hazard and vulnerability analysis • Downscaling climate change scenarios in national level • R/S data based flood analysis model development • Hazard and vulnerability analysis update
Step III Understanding disaster risk	• Risk assessment framework • Risk zoning • Risk impact assessment • Climate change impact assessment in the field • Quantitative risk estimation
Step IV Developing system for DRM	• Meteorological monitoring system • Climate change scenarios D/B system • R/S based monitoring system • Risk outlook • Social communication system
Step V Strengthening and enhancing DRM plan	• Review on existing strategies, policy, plans, laws and regulations • Flood risk education and training program • Establishing mid and long-term master plan • Risk governance and stakeholders cooperation • Risk mitigation and control plan

As shown above, according to the survey results, fundamental data (e.g. GIS/landuse Data collection, GIS/Sewer system data collection etc.) for numerical analysis and flood defense plan of ASEAN region have already been collected. This indicates that the next short-term priorities should be focused on collecting flood triggering data, in-situ data, and updating data and conducting quality control for building databases related to flood disasters, as shown in step I. However, it should be noted that survey respondents noted that most data must be regularly updated.

In step II, the most basic steps of risk analysis (historical event/damage analysis, empirical correlation model, hazard and vulnerability analysis, hazard and vulnerability analysis update) were selected as short-term priority research items. This results from the fact that there has been no sufficient research for risk analysis in most of the ASEAN region, even though they are urgent for DRR.

For step III, risk zoning which is an initial step for understanding flood disaster risk, was ranked as the top priority short-term research item, followed by risk impact assessment, quantitative risk estimation, and risk assessment framework. This result disproves that flood risk assessment has not yet been actively undertaken despite AESAN region countries recognizing it as a very important research step for flood DRM.

For step IV, establishment of monitoring systems for not only meteorology, climate change scenarios D/B, and hydrological process, but also social communication was selected as high priority items with risk outlooks for developing systems for DRM. This result means that most respondents realize that social communication systems are as important as meteorology and climate information monitoring systems.

For step V, research items related to strategies, training, policy, plans, laws, and regulations are selected as short-term priority items because both research products and resident awareness of flood disasters are important for strengthening and enhancing DRM plans. Governmental attempts to review and change existing strategies, training programs, policies, plans, laws, and regulations for effective flood DRM should be taken as follow-up measures. With these priority options, training and education of flood risk awareness also had a noteworthy number of mentions.

Table 13 indicates the survey results for long-term high priority research agenda for flood DRM.

Table 13. Long-term high-priority research agenda for flood risk management

Steps	Research Agenda
Step I Data collection	• Climate change data collection • Build up D/B system • D/B system update and advanced quality control
Step II Risk analysis	• Downscaling climate change scenarios in local level • Advanced risk forecasting model development • Real-time risk hazard and vulnerability forecasting
Step III Understanding disaster risk	• Risk assessment on climate change adaptation • Real-time risk forecasting • Flood risk forecasting GIS mapping
Step IV Developing system for DRM	• Real-time forecasting system • Early warning system • Integrated flood information system
Step V Strengthening and enhancing DRM plan	• Structural countermeasures plan • Non-structural countermeasure plan • Multi-hazard management plan • Emergency action plan

Climate change data collection and establishment of D/B system with advanced quality control were selected as long-term research items in step I, while collection of current environmental related parameter was pointed out in the short-term research items. Regarding risk analysis in step II, weather and climate related topics were ranked top level for long-term research items, which is appropriate because future risk analysis can only be done after current risk analysis. For step III, climate change adaptation was selected as a critical research topic in understanding disaster risk section based on advanced forecasting techniques.

In step IV, using versatile and elaborate systems based on cutting edge techniques were chosen for developing DRM systems. Most respondents selected real-time forecasting and early warning systems with integrated flood information system as an essential part for DRM in the ASEAN region. While governmental strategies, policies, plans, laws, and regulations were selected as short-term priority items, structural and non-structural countermeasure plans were chosen as long-term items for strengthening and enhancing DRM.

— Conclusion and Future Plan

In the past, significant flood damage has occurred in the ASEAN region. ASEAN countries have made great efforts to prevent these damages, but the conducted research was mostly composed of risk analysis using field survey data and numerical analysis. Recently, a monitoring system using radar and satellite data was constructed and operated. However, there is a lack of systematic DRM strategy construction leading to basic data investigation, database construction based on data quality control, risk analysis, understanding flood risk, developing system for DRM, and strengthening and enhancing DRM plans. In this report, we surveyed researchers' opinions working in governmental offices, international organizations, non-governmental organizations, research organizations and universities in ASEAN countries to identify short-term priority research items and long-term research items. Consequently, we were able to distinguish research items into short-term priority items and long-term items based on the five DRM research steps.

DRM begins with a survey of the data and proceeds to five stages: risk analysis, understanding disaster risk, developing system for DRM, and strengthening and enhancing DRM plan. Since each step is composed of short-term and long-term items, research should be conducted simultaneously. In the future, it is necessary to evaluate and supplement the short-term and long-term research results of each step to improve the research efficiency for flood DRM.

Landslide

— Landslide Chain

Landslide is one of the most threatening natural disasters that involves the breakup and downhill flow of rock, mud, water and anything caught in the path. In addition, it may sequentially induce rock collapse, ground slip, debris flows, and barrier lakes. Causes of landslide are heavy rainfall, earthquake, avalanche and volcanic eruptions. Of these, extreme rainfall is one of the greatest external factors that can cause Landslide induction. Precipitation triggers the transport capacity of the fluvial system and sediment transfer at the mountain front resulting on gravity-driven land flows called debris flows (De et al., 2002). In terms of landslide early warning system, the estimation of the heavy rainfall by different time scale (e.g., real-time, sub-seasonal to seasonal (S2S), seasonal and climate change) is important. Such forecasting information can be used as predictors of landslide disasters in early warning systems in different prediction time scales. In the same way, secondly induced disasters may continuously cause other disasters, especially the rainfall induced landslide disasters mechanism and its warning system as shown in Figure 14.

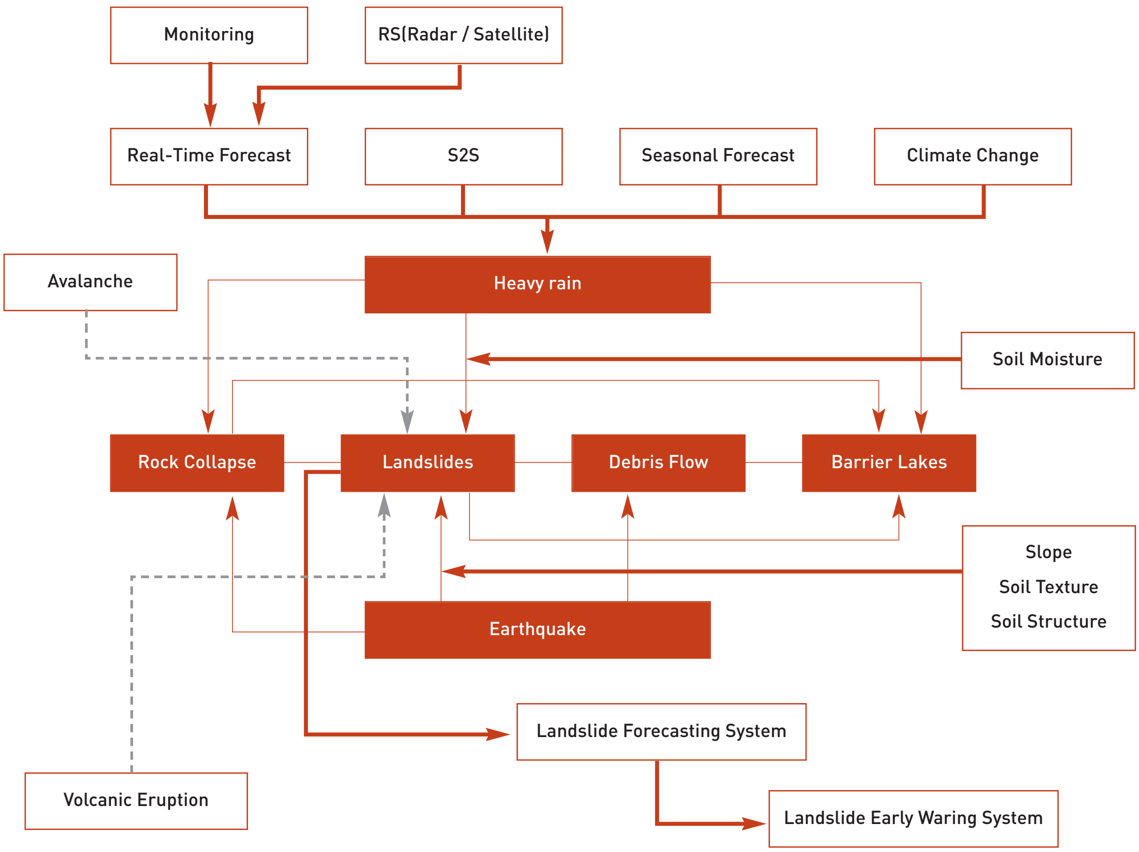


Figure 14. Rainfall-Induced landslide disaster chain and its warning system

— Landslide Regional Roadmap

When considering the components of the disaster chain and the landslide Delphi survey, the landslide research agenda matrix was developed as shown in Figure 15. The temporal scales of the landslide research agenda matrix (e.g., Current and Short-term, Mid-term and Long-term) are based on the assumption that there is no research done in landslide DRM. Because this is not the case in the ASEAN member states, it is important to identify the current status based on the matrix.

DRR Options: Risk Management; Risk Assessment; Risk Analysis

Landslide	Current and Short-term (Present ~ 2020)	Mid-term (2021~2025)	Long-term (2026~2030)
Step I Data collection	• GIS/Soil/DEM Data collection • Landslide triggering data • Socio-economic data • In-situ test / Soil test • Landslide disaster chain • Climate change data collection	• Data update and quality control • Build up D/B system • Cost effective sensors • R/S data collection • Geomorphological data setting • Climate change scenarios update	• D/B system update and advanced quality control • Real-time meteorological data and R/S data collection • Seasonal Forecasting data • Raw data service
Step II Risk analysis	• Historical event/damage analysis • Empirical correlation model • Landslide hazard and vulnerability analysis • Downscaling climate change scenarios in national level	• R/S data based landslide analysis model development • Landslide hazard and vulnerability analysis update • Downscaling climate change scenarios in local level	• Advanced landslide forecasting model development • Real-time landslide hazard and vulnerability forecasting • Seasonal Forecasting model
Step III Understanding disasters risk	• Landslide risk assessment framework • Landslide risk zoning • Landslide risk impact assessment • Climate change impact assessment in the filed of landslide	• Quantitative Landslide risk estimation • Landslide risk GIS mapping • Landslide rescue mapping • Landslide risk assessment on climate change adaptation	• Real-time landslide risk forecasting • Landslide risk forecasting GIS mapping • Landslide risk Seasonal Forecasting
Step IV Developing System for disasters risk management	• Meteorological monitoring system • Monitoring for illegal logging • Landslide annual report • Climate change scenarios D/B system	• R/S based monitoring system • Landslide outlook • Socio-economic damage analysis • Social communication system (Mass media, Tele-communication)	• Real-time forecasting system • Early warning system • Integrated landslide information system (Homepage) • Multi-hazard detection system
Step V Strengthening and enhancing disasters risk management plan	• Review on existing strategies, policy, plans, laws and regulations • Landslide risk education and training program • Establishing mid and Long-term Master plan	• Modify and maintenance of landslide related laws system • Risk governance and stakeholders cooperation • Structural measures plan • Risk mitigation and control plan	• Multi-hazard management plan • Non-structural measures plan • Diverse institutional and Multi-stakeholders cooperation • Emergency action plan • Landslide insurance

Figure15. Landslide Research Matrix

The survey questionnaire was consisted mainly as two parts. To diagnose the current status, the first part of the survey asked "where are we?", and the second part of the survey determined their priorities by providing research options by asking "what should be done first (priority)?". Landslide survey responses were received from three government offices, an international organization, two non-governmental organizations, a research organization, and two universities. The "Unnecessary" answers were ignored in the statistical analysis.

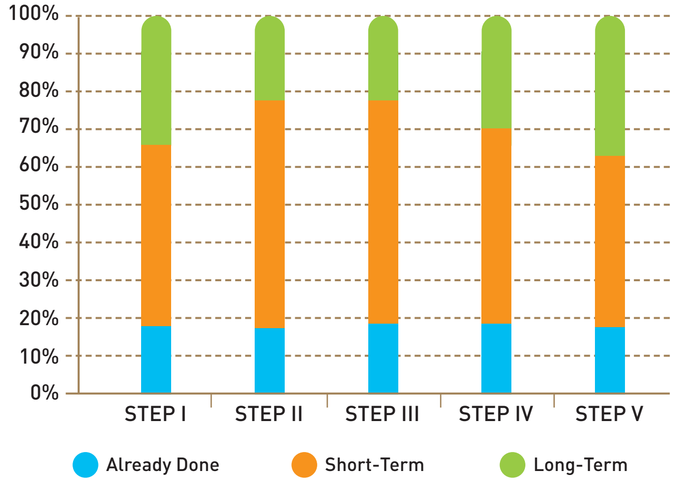


Figure16. Percentage of landslide survey responses. Blue indicates "already done" among suggested research options, and red and green indicate short-term and long-term research options, respectively. steps 1 to 5 indicate data collection, risk analysis, understanding disaster risk, developing system for DRM, and strengthening and enhancing DRM plan, respectively.

Figure 16 displays a summary of landslide survey results, which are the average of the survey results. The most distinctive pattern is that step I (data collection) is most frequently put into action, followed by step III (understanding disaster risk) and step IV (developing system for DRM). Step V (strengthening and enhancing DRM plan) is least frequently done so, followed by step II (risk analysis). Among the options of step II, many respondents selected landslide hazard and vulnerability analysis in local as a short-term priority option. In addition, the almost identical weights given to the long-term options from step III through step V suggest that step III through step V are considered to be long-term agendas across the countries answered the survey, compared to step I and step II. Lastly, step V (particularly, "Establishing mid- and long-term master plan" and "Risk mitigation plan, Multi-hazard management plan and non-structural measures plan") is most frequently regarded to be short-term options. Given that the five steps of landslide DRR are a progressive development process, the findings indicate that the landslide research agenda matrix for survey (Figure 16) is logically well organized.

Based on the result of Survey Part II (prioritization), items to be performed in short-term in ASEAN are listed in Table 14.

Table 14. Short-term high-priority research agenda for Landslide risk management

Steps	Research Agenda
Step I Data collection	• Weather and climate data/landslide triggering data • In-situ test data • Landslide disaster chain • Climate change data collection • Data update and quality control • Build up the landslide-related database system
Step II Risk analysis	• Landslide hazard and vulnerability analysis in local level • Downscaling climate change scenarios in national level • Remote sensing data based landslide analysis model development • Landslide hazard and vulnerability analysis in local level • Development of advanced landslide forecasting model
Step III Understanding disaster risk	• Landslide risk assessment framework • Landslide risk impact assessment • Climate change impact assessment in local level • Quantitative landslide risk estimation • Landslide risk GIS mapping
Step IV Developing system for DRM	• Landslide risk annual report • Remote sensing based monitoring system • Landslide risk seasonal outlook • Social communication system (e.g., Mass media, and Tele-communication) • Landslide early warning system
Step V Strengthening and enhancing DRM plan	• Establishing mid- and long-term master plan • Modify and maintenance of landslide-related laws system • Risk mitigation and control plan • Multi-hazard management plan • Non-structural measures plan

According to the survey results, many of countries already accomplished the basic data collection for landslide disaster (e.g., historical weather and climate data, in-situ data and climate change scenarios), but in some countries of it still necessary. It is understood that landslide-related data is managed well in the countries where landslides are mainly occurring such as Indonesia and Philippines. However, one of the top priorities for step I was to build a database to effectively manage and utilize the collected data and to build a high quality control system for managing landslide-induced hydro-meteorological data. In addition, regarding step II, most of the basic steps of risk analysis (e.g., hazard and vulnerability analysis, Downscaling climate change scenarios, and development of advanced forecasting model) were chosen as the urgent top-priority items. In contrast, the development of empirical correlation model(s), downscaling climate change scenarios in local level, real-time hazard and vulnerability forecasting, and build up S2S and seasonal forecasts model is considered as the longer term priority task in these countries. For understanding disaster risk in step III, quantitative landslide risk assessment has carried out as a top priority in most of the countries and the landslide risk assessment and its climate change impact assessment in local level were second priority. The GIS mapping of landslide risk and risk forecasts are required as well. However, the scientific understanding such as climate change impacts on landslide risks and landslide seasonal forecasts are necessary not only for model development but also for disaster risk mitigation and preparedness. step IV is identified that the system development for DRM, and step V is identified that the strengthening and enhancing for DRM. step IV is considered under progress, but step V is in early stages in ASEAN region. For system development for DRM, landslide early warning system is appeared top priority in most of the countries, and followed by R/S based monitoring system, landslide seasonal outlook and social communication system (e.g., Mass media, and Tele-communication). For strengthening and enhancing of DRM plans, the risk mitigation and control plan and establishing mid- and long-term master plan are chosen as a top-priority. Governmental attempts to review and modify for maintenance of landslide -related laws system and establish risk mitigation and control plans for effective landslide DRM should be taken as follow-up measures. Multi-hazard management plan and non-structural measures plan are required as well. With these priority options should also pay attention to landslide risk awareness training and education. In Table 15, long-term priority options in landslide disasters are also listed.

Table 15. Long-term high-priority research agenda for landslide risk management

Steps	Research Agenda
Step I Data collection	• GIS/soil data collection • Socio-economic data collection • Cost effective sensors • Geomorphological data • Remote sensing data • Sub-seasonal to seasonal (S2S), and seasonal forecasts data • Climate change scenarios • Database system and advanced quality control • Real-time meteorological data collection • Raw data service
Step II Risk analysis	• Historical events/damage analysis • Developing empirical correlation model • Downscaling of climate change scenarios in local level • Real-time hazard and vulnerability forecasting • Build up S2S, and seasonal forecasts model
Step III Understanding disaster risk	• Landslide risk zoning • Landslide rescue mapping • Landslide risk assessment under climate change • Landslide risk forecasts using S2S and seasonal forecasts information • Real-time landslide risk forecasting • GIS mapping by landslide risk forecasts
Step IV Developing system for DRM	• Hydro-meteorological monitoring system • Monitoring system on illegal logging • Climate change scenarios D/B system • S2S, and seasonal forecasts system • Socio-economic damage analysis system • Real-time forecast system and S/W development • Integrated information system and services (e.g., Homepage)
Step V Strengthening and enhancing DRM plan	• Reviewing existed strategy, policy and laws • Landslide risk education and technical training • Risk governance and stakeholders cooperation • Structural measures plan in landslide • Diverse institutional and multi-stakeholders coordination • Emergency action plan • Landslide insurance

— Conclusion and Future Plan

With increasing population and concerns of climate change, the risk and vulnerability of landslide disaster is likely to increase substantially in the ASEAN region. Especially, elevated regions can have greater damage caused by landslide disasters on the agricultural activities and urban development on slopes. According to the survey, the most vulnerable country to landslides in the ASEAN region was Indonesia, followed by Philippines. In these countries and other vulnerable countries, landslide-related DRR research efforts, development of sustainable development plans, and developing integrated management system should be followed. In the past few years, the ASEAN region countries have focused on collecting the landslide relevant basic data and distinguishing the landslide disaster-effected areas. Most of the governmental activities and countermeasures are focused on in response and restoration after landslide disasters. These disasters management patterns need to change using recent advanced technologies. In addition, these activities and efforts should be gradually changed to prevent and prepare for landslide disasters in advance such as landslide early warning systems. As well as, for the real-time landslide forecasts and its early warning system based on high-quality of monitoring data (e.g., cost effective sensors and remotely sensed data) is gradually expanded. Moreover, advanced seamless predictions using climate models are needed in different time scales (e.g., sub-seasonal to seasonal, seasonal, and climate change) for landslide disaster management. Additionally, landslide risk impact assessment and hazard mapping using GIS tool is also important to manage landslide disasters, and for the effort of strengthening and enhancing DRR/DRM. Among those, international cooperation between ASEAN countries, governments, and institutions is important, and it is necessary to establish cooperative relations with local communities.

Typhoon

— Typhoon Chain

Primary impacts of typhoons include storm surge, strong waves, strong wind, and heavy rain. Destructive influences of typhoons are dependent on its frequency, intensity, and location. Usually the most severe damages from typhoon are attributed to storm surge and waves that may result in coastal floods with or without destroying banks. The coastal flood can lead not only to transportation systems, building/house damage, and malfunction of machinery, but also to water pollution-caused diseases and pest injuries. Embankments can also be damaged by strong winds. In addition, strong winds can result in tree damage and failed electricity systems as well as damages to buildings and houses. Heavy rainfall accompanied by typhoons may cause floods and landslides both inland and coastal areas. These impacts of typhoon are inter-related processes as summarized in Figure 17.

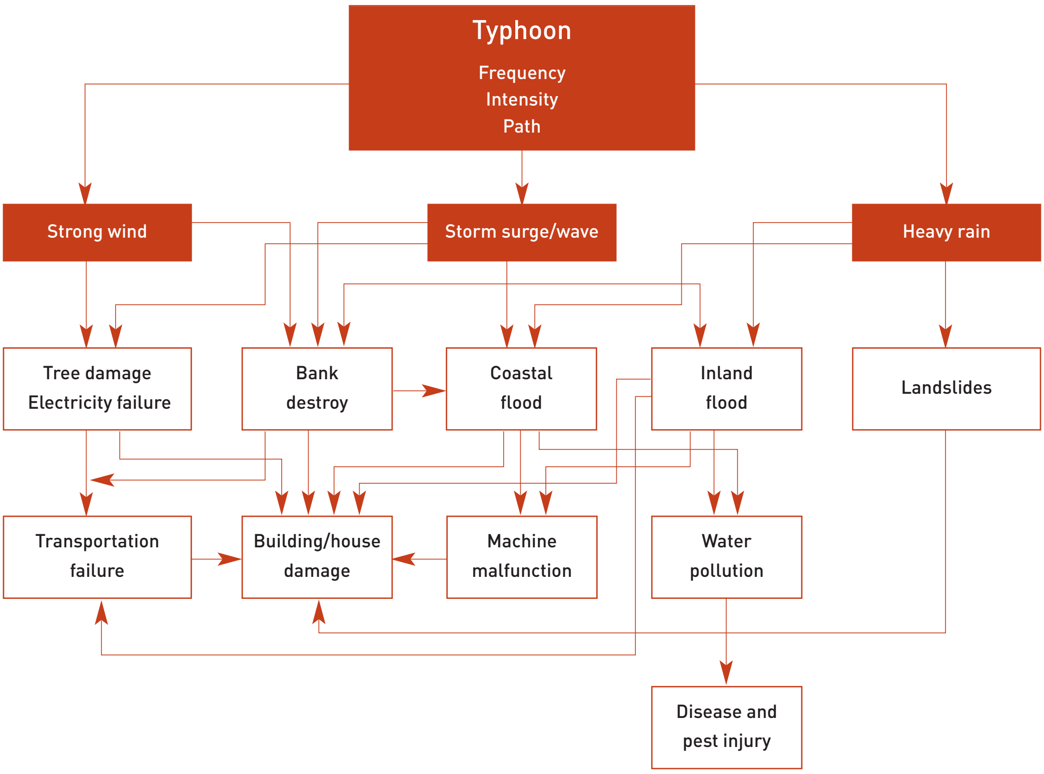
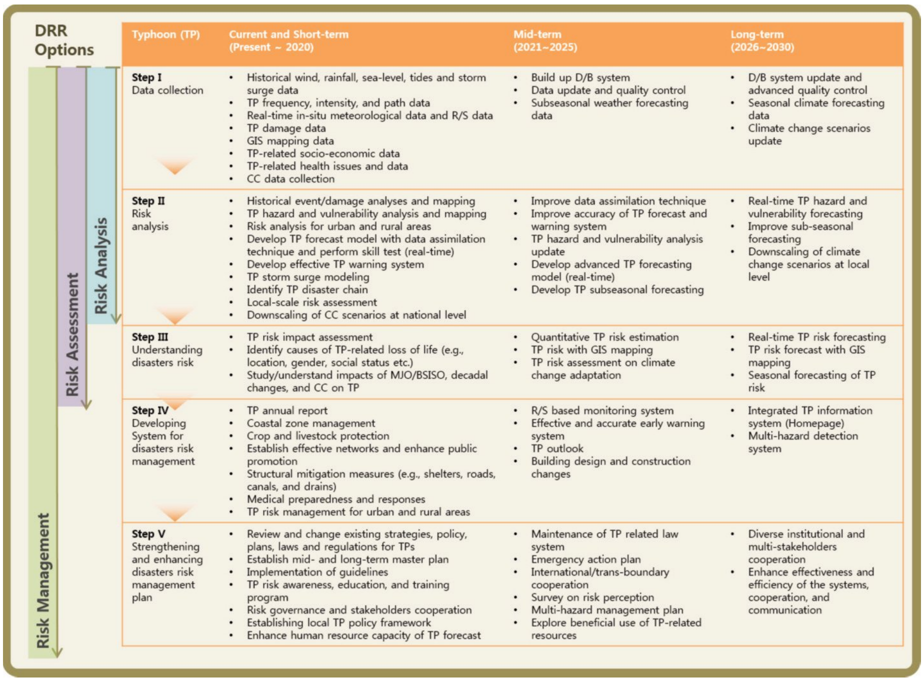


Figure 17 Typhoon Disaster Chain

— Typhoon Regional Roadmap

Figure 18 describes an ideal research roadmap matrix for typhoon DRM. This is established under the assumption that there is no existing framework for typhoon risk reduction.



Typhoon (TP)	Current and Short-term (Present ~ 2020)	Mid-term (2021~2025)	Long-term (2026~2030)
Step I Data collection	• Historical wind, rainfall, sea-level, tides and storm surge data • TP frequency, intensity, and path data • Real-time in-situ meteorological data and R/S data • TP damage data • GIS mapping data • TP-related socio-economic data • TP-related health issues and data • CC data collection	• Build up D/B system • Data update and quality control • Subseasonal weather forecasting data	• D/B system update and advanced quality control • Seasonal climate forecasting data • Climate change scenarios update
Step II Risk analysis	• Historical event/damage analyses and mapping • TP hazard and vulnerability analysis and mapping • Risk analysis for urban and rural areas • Develop TP forecast model with data assimilation technique and perform skill test (real-time) • Develop effective TP warning system • TP storm surge modeling • Identify TP disaster chain • Local-scale risk assessment • Downscaling of CC scenarios at national level	• Improve data assimilation technique • Improve accuracy of TP forecast and warning system • TP hazard and vulnerability analysis update • Develop advanced TP forecasting model (real-time) • Develop TP subseasonal forecasting	• Real-time TP hazard and vulnerability forecasting • Improve sub-seasonal forecasting • Downscaling of climate change scenarios at local level
Step III Understanding disasters risk	• TP risk impact assessment • Identify causes of TP-related loss of life (e.g., location, gender, social status etc.) • Study/understand impacts of MJO/BSISO, decadal changes, and CC on TP	• Quantitative TP risk estimation • TP risk with GIS mapping • TP risk assessment on climate change adaptation	• Real-time TP risk forecasting • TP risk forecast with GIS mapping • Seasonal forecasting of TP risk
Step IV Developing System for disasters risk management	• TP annual report • Coastal zone management • Crop and livestock protection • Establish effective networks and enhance public promotion • Structural mitigation measures (e.g., shelters, roads, canals, and drains) • Medical preparedness and responses • TP risk management for urban and rural areas	• R/S based monitoring system • Effective and accurate early warning system • TP outlook • Building design and construction changes	• Integrated TP information system (Homepage) • Multi-hazard detection system
Step V Strengthening and enhancing disasters risk management plan	• Review and change existing strategies, policy, plans, laws and regulations for TPs • Establish mid- and long-term master plan • Implementation of guidelines • TP risk awareness, education, and training program • Risk governance and stakeholders cooperation • Establishing local TP policy framework • Enhance human resource capacity of TP forecast	• Maintenance of TP related law system • Emergency action plan • International/trans-boundary cooperation • Survey on risk perception • Multi-hazard management plan • Explore beneficial use of TP-related resources	• Diverse institutional and multi-stakeholders cooperation • Enhance effectiveness and efficiency of the systems, cooperation, and communication

Figure 18. Ideal research matrix for typhoon (TP) risk management

Acronym
TP: Typhoon
GIS: Geographic Information System
CC: Climate Change
MJO: Madden–Julian Oscillation
BSISO: Boreal Summer Intra-seasonal Oscillation
R/S: Remote sensing

Typhoon survey responses were received from five government offices, one international organization, one research organization, and two universities. The "Unnecessary" answers were ignored in the statistical analysis. Figure 18 displays a summary of typhoon Survey I results, indicating percentages that were selected as "already-done", "short-term", or "long-term" research agendum for each DRR steps. The most distinctive pattern is that step I (Data collection) has the highest level of "already-done" (37%), followed by step II (22%), and step V (Strengthening and enhancing disaster's risk management plan) has the lowest level of "already-done". Within step I, 34% and 29% responses were selected as short- and long-term research issues, suggesting that data collection (e.g., health-issue data collection) is still insufficient. Almost identical weights given to the short-term options from step III through step V suggest that step III through step V are considered to be short-term agendas across the countries that answered the survey, compared to step I (Data collection) and step II (Risk analysis). Lastly, step V (particularly, "Diverse institutional and multi-stakeholder cooperation" and "Enhance effectiveness and efficiency of the system, cooperation, and communication") is most frequently regarded as long-term options. Given that the five steps of typhoon DRR are a progressive development process, this finding indicates that the typhoon Research Agenda Matrix for survey (Figure 19) is logically well organized.

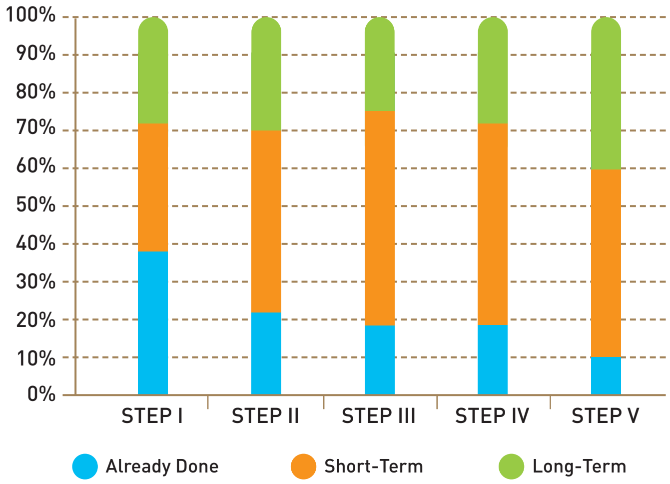


Figure 19. Percentage of survey responses for typhoon

Based on the result of Survey Part II (prioritization), items to be performed in short-term in ASEAN are selected as in Table 16.

Table 16. Short-term high-priority research agenda for typhoon (TP) risk management

Steps	Research Agenda
Step I Data collection	• TP-related socio-economic data • Build up D/B system • D/B system update and advanced quality control • Seasonal climate forecasting data • Climate change scenarios update
Step II Risk analysis	• Historical event/damage analyses and mapping • TP hazard and vulnerability analysis and mapping • Risk analysis for urban and rural areas • Develop TP forecast model with data assimilation technique and perform skill test (real-time) • Develop effective TP warning system • TP storm surge modeling
Step III Understanding disaster risk	• Identify causes of TP-related loss of life (e.g., location, gender, social status etc.) • Study/understand impacts of MJO/BSISO, decadal changes, and CC on TPs • Quantitative TP risk estimation • TP risk with GIS mapping • TP risk forecast with GIS mapping
Step IV Developing system for DRM	• TP risk management for urban and rural areas • Effective and accurate early warning system • Provide seasonal TP outlook • Integrated TP information system (e.g., homepage)
Step V Strengthening and enhancing DRM plan	• Review and change existing strategies, policy, plans, laws and regulations for TPs • Implementation of guidelines • TP risk awareness, education, and training program • Establishing local TP policy framework • Enhance human resource capacity of TP forecast • Emergency action plan

According to the survey results, basic data collection for typhoon disasters (e.g., historical wind, rainfall, sea-level, tides and storm surge data, typhoon damage data, and climate change scenario data) have already been accomplished to a great extent. This may be due to the fact that most survey respondents were government officials and scientists from ASEAN countries, such as Philippines, Vietnam, and Thailand, who have had past typhoon disaster experiences and their management. However, the establishment of database systems and updates, as well as advanced quality control should follow to make good use of the data collected. This is reinforced by the fact that it was selected as one of the top-priority items for step I. In contrast, in regards to step II, most of the basic steps of risk analysis (e.g., historical event/damage analyses and mapping, typhoon hazard and vulnerability analysis and mapping) were chosen as the top-priority items. In addition, the development of a typhoon forecast model, a storm surge model, and an effective typhoon warning system is viewed as the most urgent tasks in these countries.

For step III, typhoon risk impact assessments have been carried out in most of the countries. However, the scientific understanding such as modulation on large-scale atmospheric/oceanic circulations (e.g., BSISO and various types of ENSO) and climate change on typhoon characteristics are necessary not only for model development but also for disaster risk mitigation and preparedness. GIS mapping of typhoon risk and risk forecast are also required.

For step IV and step V, it is identified that the system development for typhoon DRM is under progress, but the enhancement of DRM plans in ASEAN is in its early stages. For system development for DRM, an effective and accurate early warning system, seasonal typhoon outlook, as well as an integrated typhoon information system appear to be the top priorities. For strengthening DRM plans, the enhancement of human resource capacity and emergency action plan are chosen to be top priority. Governmental attempts to review and change existing strategies, relevant policies, law and regulations for effective typhoon DRM should be taken as follow-up measures. With these priority options, training and education of typhoon risk awareness also requires attention.

Based on selection frequency in Survey I, long-term research topics are listed in Table 17.

Table 17. Long-term high-priority research agenda for typhoon risk management

Steps	Research Agenda
Step I Data collection	• TP-related health issues and data
Step II Risk analysis	• Identify TP disaster chain • Improve data assimilation technique • Improve accuracy of TP forecast and warning system • Develop TP subseasonal forecasting systems • Improve sub-seasonal forecasting
Step III Understanding disaster risk	• TP risk assessment on climate change adaptation • Real-time TP risk forecasting
Step IV Developing system for DRM	• TP annual report • Coastal zone management • Crop and livestock protection • Establish effective networks and enhance public promotion • Structural mitigation measures (e.g., shelters, roads, canals, and drains) • Medical preparedness and responses • Multi-hazard detection system
Step V Strengthening and enhancing DRM plan	• Risk governance and stakeholders cooperation • Multi-hazard management plan • Explore beneficial use of TP-related resources • Diverse institutional and multi-stakeholders cooperation • Enhance effectiveness and efficiency of the systems, cooperation, and communication

While establishment of D/B system was one of the urgent priority items in ASEAN (Table 17), its update and advanced data quality control turned to be a long-term research item for step I. As socio-economic variables promptly change in time, their updates and quality control are important issues in DRR. For step II, advanced techniques and information such as data assimilation technique and sub-seasonal forecasting systems were chosen. Reliable sub-seasonal forecasting system can extend lead time of TP forecasts and allow for more efficient early warning and preparation for TPs.

The long-term topics in step IV and step V include broad issues. Among them, multi-hazard detection and management emerge as critical issues these days, not only in ASEAN, but also globally. Multi-hazard risk analyses and assessment require multidisciplinary analyses and strong collaboration among the related experts. Meanwhile, effective cooperation and communication between multiple stakeholders and governances could lead to successful DRM in practice. Adequate approaches and methodology promoting the cooperation and communication need to be investigated and developed.

— Conclusion and Future Plan

In the past years, data collection and risk mapping have been a primary focus in the field of typhoon risk management in ASEAN. These processes need to be upgraded and quality-controlled by new and advanced techniques. Meanwhile, relatively insufficient efforts were made for the model development such as typhoon forecast models, storm surge models, and typhoon risk forecast models, due to the limitations of financial resources and technical advances. Since these modeling approaches are critical for improving early warning systems and disaster preparedness and mitigation, they were emphasized as one of the short-term priority in the survey. Recent advances in satellite technologies and modeling approaches (machine learning and artificial intelligence etc.) can be applied to develop aforementioned models, which can enhance typhoon DRM cost-effectively in ASEAN. Scientific investigation and understanding on the characteristics of typhoon risk should be also accompanied.

Scientific and technological advances in typhoon monitoring and prediction do not assure successful risk reduction in practice. Additionally, governmental and institutional efforts developing and enhancing DRM systems (e.g., development of integrated typhoon information system and effective and accurate early warning system, and implementation of guidelines) should be also followed. Recently, governmental, institutional, and furthermore international cooperation are emphasized along with local communities.

Earthquake, Volcano, and Tsunami

— Earthquake/Volcano/Tsunami Regional Roadmap

As previously addressed, a research matrix was given only based on survey responses from some respondents for earthquake, volcano, and tsunami disaster types without prioritization of the short-term research agenda. The survey questionnaire for the three disaster types was developed to only get suggestions from respondents. There were 6 responses for earthquake, 6 responses for tsunami, and 2 responses for volcano.

The presented research matrix for earthquake/tsunami may be viewed as mere suggestions that have not been fully reviewed by experts. Short-term and long-term research roadmaps for these disaster types can be dealt with in depth in further research. A research matrix for volcano could not be created because of the lack of responses.

DRR Options

Risk Management

Risk Assessment

Risk Analysis

Steps/Time Scales	Current and Short-term (Present ~ 2020)	Mid-term (2021~2025)	Long-term (2026~2030)
Step I Data collection	• Collect Peak Ground Acceleration (PGA) data • Collect Earthquake intensity data • Collect focal mechanism of earthquake events • Data collection related to evacuation and/or relocation • Collect and update Earthquake/Tsunami Catalogue	• Collect aftershock distribution • Collect aftershock attenuation • Collect mining explosion events	• Collect earthquake precursors • Collect stress change of Earthquake events • Collect phase identification data
Step II Risk analysis	• Probabilistic risk assessment • Analysis of ground-motion attenuation • Analysis of intensity scale of the Earthquake • Maintain and update risk maps	• Analysis of aftershock probability • Develop evacuation and/or relocation plan	• Evaluate and analyze earthquake response mechanisms • Earthquake prediction • Capacity building for technicians who work in risk analysis
Step III Understanding disaster risk	• Community awareness campaign	• Training and workshops for both central and local government as well as NGOs	• Emphasize local communities' safety • Develop plan/regulation to keep people out of risk zones • Public awareness/knowledge transfer about earthquake-generated tsunami
Step IV Developing System for disaster risk management	• Form national team with stakeholders from multi-sectors • Expand the system into central, local and community levels • Develop Earthquake/Tsunami Early Warning System	• Train academia and government officials	• Formulated system course and expand into primary school, high school, universities and institutions • International collaborations between developing and developed countries
Step V Strengthening and enhancing disaster risk management plan	• Develop capacity of government officials in DRM • Develop guidelines for elaborating earthquake-generated tsunami response plan	• Training of the trainers in DRM who will be the chain of connection between officials and people in term of risk prevention • Elaborate earthquake-generated tsunami response plan for high risk provinces and areas	• Boost active participation and disaster awareness of the young generation • Develop initiatives by the local and central governments • Implement earthquake-generated tsunami response plan

Figure 20. Research Matrix for Earthquake and Tsunami

— Conclusion and Future Plan

Exposure to geophysical disasters of earthquake, tsunami, and volcanic eruptions may not increase as much as hydro-meteorological disasters under this changing climate, impacts and vulnerability to those disasters of ASEAN people will increase in future, because of the population growth and accelerated urbanization in areas prone to geophysical disasters.

It is known that the primary cause of earthquake-related death is trauma due to building collapse (Doocy et al., 2013). Impacts are more severe in densely populated areas, and specific population groups are more affected because of their lack of mobility.

For disasters of earthquake, tsunami, and volcanic eruptions, efforts in ASEAN should be made to diminish vulnerability of people and to enhance resilience of the communities in order to reduce risk of injury and death in future (Shapira et al, 2016). More diverse and people-centered preventive approach is essential in future research.

Country-Based Research Roadmap

Brunei Darussalam

Cambodia

Indonesia

Lao PDR

Malaysia

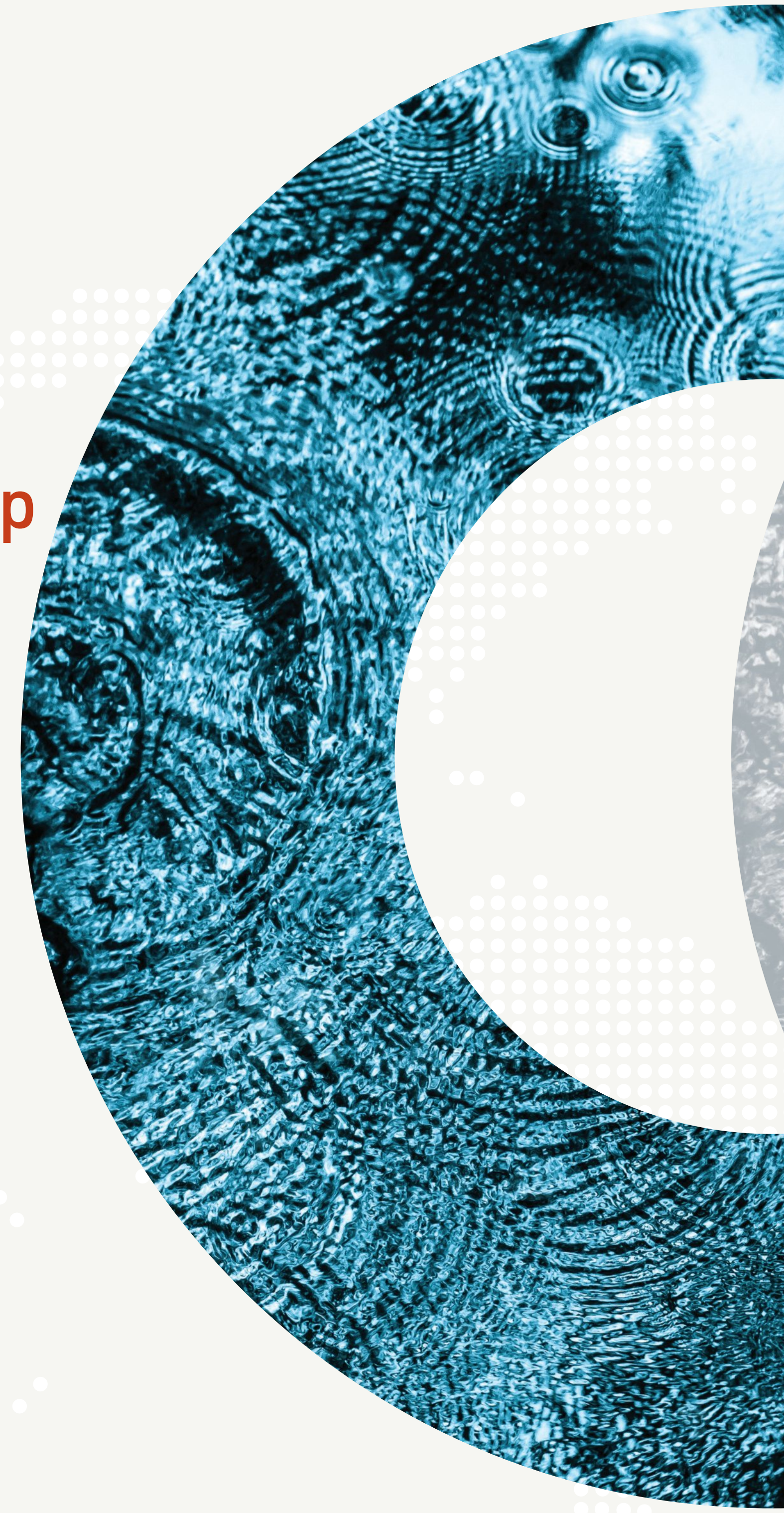
Myanmar

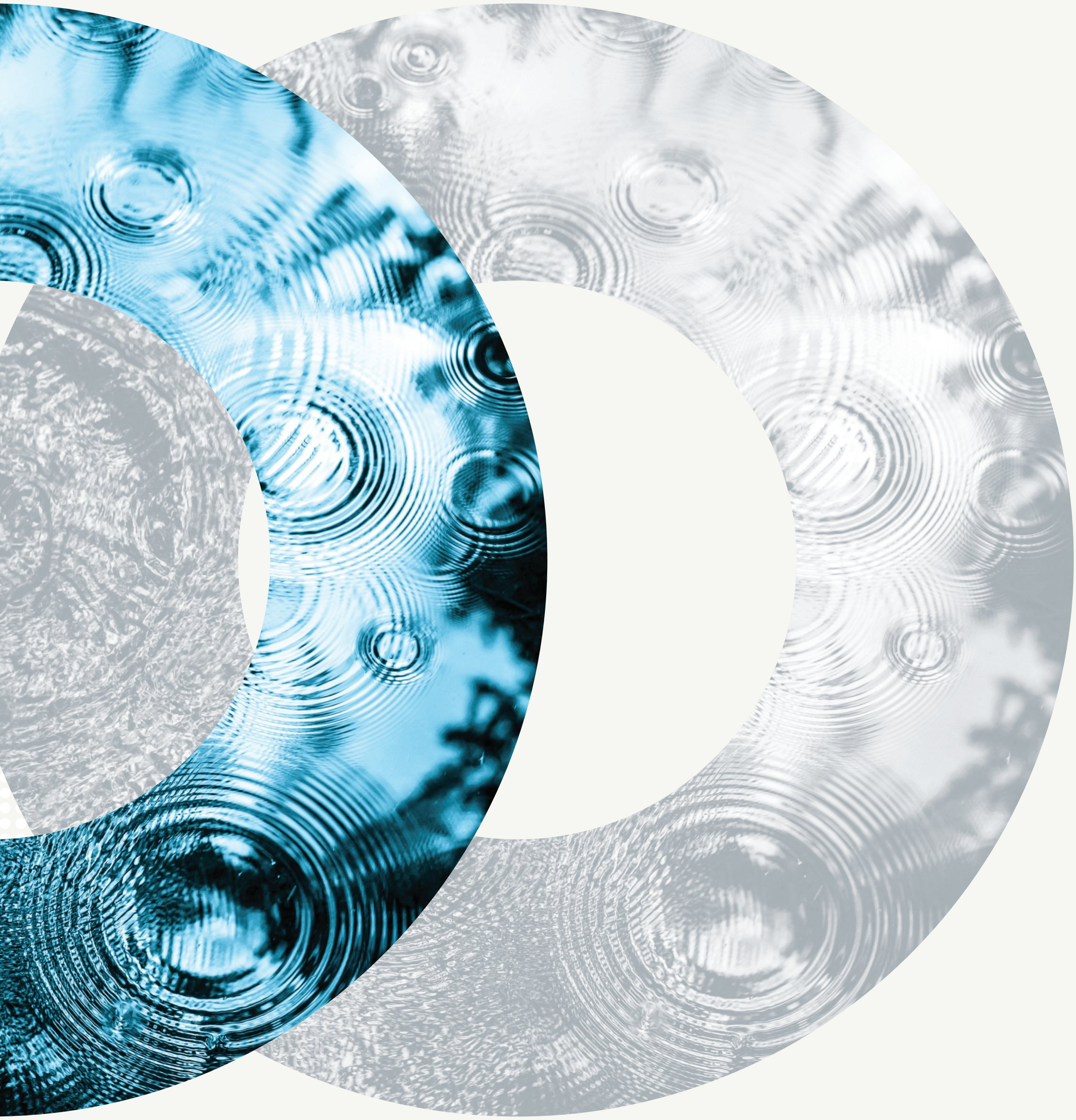
Philippines

Singapore

Thailand

Viet Nam





Country-Based Research Roadmap

The country-based (national-level) research roadmap is for each ASEAN country, with more country-specific information.

Brunei Darussalam

Country Demographics/Disaster Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Brunei	434,448	82	5,272	77.40%
Natural Disasters (EM-DAT, 2017)				
Disaster type	Event count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	-	-	-	-
Earthquake	-	-	-	-
Flood	-	-	-	-
Landslide	-	-	-	-
Tsunami	-	-	-	-
Typhoon	-	-	-	-
Volcano	-	-	-	-

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Drought

No droughts have recorded in the past 30 years, indicating that drought may not be a major natural disaster in Brunei. However, droughts can happen even under a wet climate. When necessary, future efforts need to include DRM frameworks.

— Flood/Inundation

In Brunei, National Disaster Council (NDC) and National Disaster Management Centre (NDMC) were established by Disaster Management Order (DMO) 2006. Floods, including flash flood hazard maps, have been prepared based on probable floods by Danish Hydraulic Institute (DHI) but the maps do not consider climate change impacts.

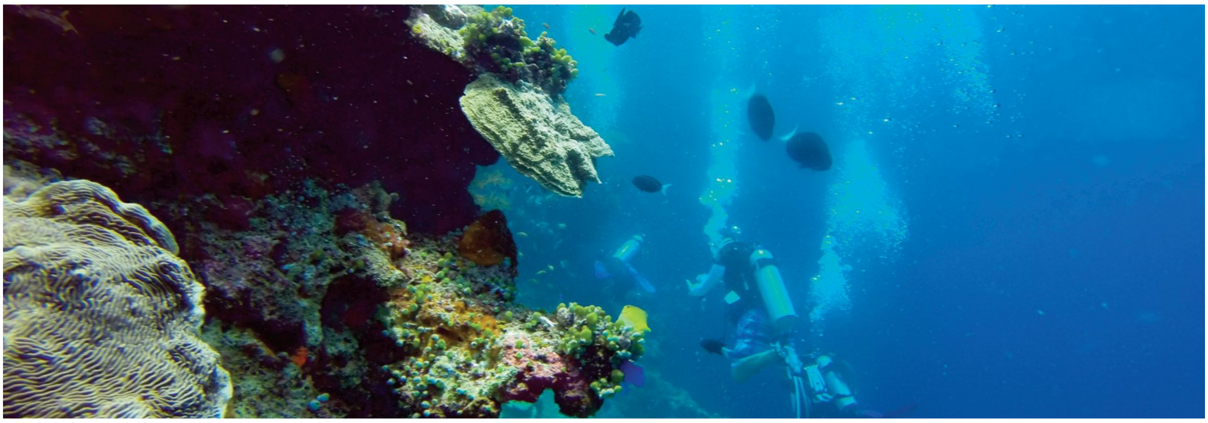
Regarding flood and storm risk management, there is no guideline and standard for DRR against flood and storm so that it is recommended that building elevated houses in flood prone area around the rivers with capacity building of DRM experts in local area.

— Landslide

The risk of landslide in Brunei is considered to be insignificant. Based on the EM-DAT (2017) survey, landslide and its damage have not been reported in the past 30 years in Brunei. However, GFDRR (2012) reported that Brunei has the highest percentage of population at landslide risk, followed by Philippines and Indonesia. Brunei's hilly areas are at risk of landslide. Therefore, landslide risk cannot be ignored in Brunei and careful consideration should be given to factors that can affect landslides such as frequency, magnitude, and intensity of landslide as well as impacts of climate change.

— Typhoon

No typhoon damage has been reported in the past 30 years and typhoon risk is considered to be minimal in Brunei. However, typhoon risk cannot be ignored in Brunei considering the factors of modifying frequency, paths, and intensity of TP. One of the critical factors is climate change. Therefore, impacts of global warming on typhoon risk in Brunei and neighboring countries need to be carefully considered.



Cambodia

Country Demographics/Disaster Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Cambodia	16,076,370	91	176,469	20.80%
Natural Disasters (EM-DAT, 2017)				
Disaster type	Event count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	6	-	9,050,000	138,000
Earthquake	-	-	-	-
Flood	18	1,641	13,275,587	1,419,100
Landslide	-	-	-	-
Tsunami	-	-	-	-
Typhoon	3	44	178,091	10
Volcano	-	-	-	-

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Drought

The meteorological observation systems in Cambodia include 20 synoptic stations located mainly in populated cities as of 2010. An ongoing project is conducted to improve gauging network up to 60 automatic synoptic stations for both cities and rural areas. A UNDP project is ongoing for strengthening climate information in Cambodia. These imply that meteorological observations in Cambodia are insufficient to handle drought risks at local and regional levels, while drought risk maps can be obtained by the CAMDI disaster database. Currently, drought management in Cambodia seems to focus on responsive measures such as providing advisory and supplying drinking water to locations of drought events.

Given the high exposure to increasing drought risks under climate change, establishing drought monitoring systems is an urgent agendum in Cambodia. The establishing data collection systems and finding available regional and global data sources will improve current drought risk maps. Due to limited data availability, establishing meteorological and hydrological gauging networks would be the first task in Cambodia. Expanding data category and quality control may be on the long-term agenda. The research agenda that seems to be in high-priority are listed in Table 18. However, given the weakness of the current Cambodian drought management framework, all of the research agenda in the matrix may be necessary.

Table 18. Research agenda for drought risk management in Cambodia

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Collecting meteorological data • Collecting geophysical and hydrological data	• Expanding data categories related to drought • Updating database and advancing quality control techniques
Step II Risk Analysis	• Analysis of drought occurrence and severity • Assessing spatial extent of droughts	• Updating spatial-temporal drought analyses
Step III Understanding disaster risk	• Mapping drought risks in terms of hazard, exposure, and vulnerability	• Assessing climate change impacts on drought risk
Step IV Developing system for DRM	• Developing drought monitoring system	• Developing real-time forecasting and early warning system
Step V Strengthening and enhancing DRM plan	• Developing drought risk education and training program	• Evaluating and revising drought mitigation plans periodically

— Flood/Inundation

Over the past decade, 18 floods have been recorded in Cambodia (EM-DAT, 2017). As a result, more than 13 million people were affected, resulting in 1,641 casualties and $ 1.4 million in damages. The total casualties and damages in Cambodia caused by floods in the last 10 years is reported to be the fifth highest among the ASEAN countries, while the number of flood events has been ranked to be the eighth highest. This results from fact that although the frequency of flood event in Cambodia is relatively low, event intensity is higher than the flood events experienced in the other ASEAN member countries.

Cambodia has two main seasons, dry (from October to late April) and rainy season (from May to late September). The past flood events in Cambodia showed that the light flood events were caused by typhoons and torrential rainfall. Many provinces were affected by annual river flooding along with the two major watersheds, Mekong River and Tonle Sap Lake. The average rainfall level in September is increasing from the last ten years. This was a major trigger of flooding. Therefore, climate change is a challenge in Cambodia, especially in the form of changing weather conditions and disasters.

The next table shows the research roadmap including short-term priority items and long-term items for Cambodia DRR based on online survey.

Table 19. Research agenda for flood risk management in Cambodia

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Flood triggering data • In-situ test data • Disaster chain • Data update and quality control • R/S data collection • Geomorphological data setting • Climate change scenarios update	• Climate change data collection • Build up D/B system • D/B system update and advanced quality control
Step II Risk Analysis	• Historical event/damage analysis • Empirical correlation model • Hazard and vulnerability analysis • Downscaling climate change scenarios in national level • R/S data based flood analysis model devel-opment • Hazard and vulnerability analysis update	• Downscaling climate change scenarios in local level • Advanced risk forecasting model development • Real-time risk hazard and vulnerability forecasting
Step III Understanding disaster risk	• Risk assessment framework • Risk zoning • Risk impact assessment • Climate change impact assessment in the field • Quantitative risk estimation	• Risk assessment on climate change adaptation • Real-time risk forecasting • Flood risk forecasting GIS mapping
Step IV Developing system for DRM	• Meteorological monitoring system • Climate change scenarios D/B system • R/S based monitoring system Risk outlook • Social communication system	• Real-time forecasting system • Early warning system • Integrated flood information system
Step V Strengthening and enhancing DRM plan	• Review on existing strategies, policy, plans, laws and regulations • Flood risk education and training program • Establishing mid and long-term master plan • Risk governance and stakeholders cooperation	• Structural countermeasures plan • Non-structural countermeasure plan • Multi-hazard management plan Emergency action plan

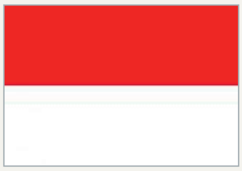
— Landslide

In geographically, landslide disasters are not common in Cambodia. Landslide damages are occasionally reported in the mountainous areas in the northern part of Cambodia, and riverbank collapses are relatively frequent and impact people when parts of the riverbanks collapse. For example, 61 families were affected by river landslide occurred in April 2, 2008 on the Tonle Sap, about 6km north of Phnom Penh, and ten houses on the banks of the Bassac river in Kandal province were damaged by a river landslide in March 27, 2017. According to the survey from EM-DAT (2017) for Cambodia, there has been no damage reported in the past 30 years. This shows that landslide risk is considered to be minimal in Cambodia. However, landslide risk cannot be ignored in Cambodia, considering the factors of modified frequency, magnitude, and intensity of landslide due to climate change. Therefore, impacts of global warming on landslide risk in Cambodia and neighboring countries need to be carefully considered.

— Typhoon

In Cambodia, typhoon landfall occurs very occasionally, and most floods are associated with storms rather than TPs. Thus, typhoon risk is lower than the other disaster risks such as floods, lightning, and droughts. However, Typhoon Ketsana, which hit Cambodia in 2009, was a wake up call for typhoon risk in Cambodia. Ketsana resulted in the death of 43 persons, widespread damage to houses, rice crops, and infrastructure, which estimated about USD 132 million and the amount of USD 191 million required for the recovery. Several factors can increase typhoon risk in Cambodia: changes of typhoon tracks and intensity, global warming, population increase and economic growth in coastal regions, and fast urbanization and poverty. Under this situation, current/short-term DRM options in data collection (step I) and risk analysis (step II) described in the ideal typhoon research roadmap matrix (Figure 18) are suggested as high priority. Among them, development of typhoon monitoring systems and effective typhoon warning systems with perception changes for typhoon disaster risk are the most crucial.

Indonesia



Country Demographics/Disasters Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Indonesia	263,510,146	146	1,811,066	53.40%
Natural Disasters (EM-DAT, 2017)				
Disaster type	Event count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	4	683	1,080,000	89,000
Earthquake	72	12,162	7,968,448	7,066,456
Flood	145	4,759	7,494,336	6,706,909
Landslide	49	1,807	385,936	146,745
Tsunami	6	167,052	590,684	4,506,600
Typhoon	1	-	1,315	-
Volcano	30	507	486,220	195,000

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Drought

Indonesia experienced significant casualties and economic losses by 10 drought episodes for 1966-2015 (EM-DAT, 2016). Droughts can cause forest and peatland fires with environmental and health problems (e.g., air pollution and respiratory illnesses). Drought is a common natural phenomenon across Indonesia. SPI is currently used for drought detection for agricultural and hydrological applications. 120+ meteorological and hydro-climatological stations are installed in Indonesia. The Agency for Meteorology, Climatology, and Geophysics (BMKG) regularly produces weather and climate forecasts for the stakeholders related to water resources. Because forest fires are a keen interest for not only Indonesia, but also for the surrounding countries, a fire risk rating system has been developed based on real-time weather data and 3-day forecasts, implying that droughts are being monitored at a fine temporal resolution. Because operational drought monitoring systems are well established in Indonesia among the ASEAN region, improving the systems and policy governance would be the next steps, as well as consideration of socioeconomic conditions in the system. Table 20 shows the research agenda for Indonesia.

Table 20. Research agenda for drought risk management in Indonesia

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Collecting socioeconomic data • Collecting projections of socioeconomic conditions • Expanding data categories related to drought	• Updating database and advancing quality control techniques
Step II Risk Analysis	• Assessing resource inventory and identify groups at risk • Assessing social resilience to drought impacts	• Establishing forecast-based risk analysis framework
Step III Understanding disaster risk	• Assessing risk of changing socioeconomic conditions • Developing mitigation and adaptation plans under changing conditions	• Assessing drought hazard and vulnerability under forecasted climate conditions
Step IV Developing system for DRM	• Finding predictors of drought for early warning	• Developing real-time forecasting and early warning system • Developing integrated multi-hazard detection systems
Step V Strengthening and enhancing DRM plan	• Evaluating and revising drought mitigation plans periodically • Identifying and filling institutional gaps	• Evaluating and revising drought mitigation plans periodically

— Flood/Inundation

Over the past decade, 145 flood events have been recorded in Indonesia, which is ranked as number one in ASEAN countries (EM-DAT, 2017). There were more than 7 million people were affected, with 4,759 casualties and $ 6.7 million in damages. The total casualties and amount of damage in Indonesia caused by floods in the last 10 years is reported to be number one among ASEAN countries, while the number of affected people has been ranked fifth (which is the opposite phenomena from Thailand). These statistics show that that Indonesia has high frequency and intensity of flood events, but has a narrower impact area and range when compared to other ASEAN members.

In Indonesia, BMKG is the responsible agency for meteorological and rainfall observation and weather forecast. BMKG is conducting meteorological and rainfall data observations using satellite images of Himawari. In addition, downscaling of the results of various GCM models was conducted for all of the country. Based on weather monitoring and climate data, various research projects were conducted, such as hazard and risk mapping for floods. Therefore, items like updating the data and monitoring systems were mainly selected as short-term items. The following table shows the research roadmap for Indonesia, including short-term priority items and long-term items for Indonesia DRR.

Table 21. Research agenda for flood risk management in Indonesia

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Flood triggering data • In-situ test data • Disaster chain • Data update and quality control • R/S data collection • Geomorphological data setting • Climate change scenarios update	• Climate change data collection • Build up D/B system • D/B system update and advanced quality control
Step II Risk Analysis	• Historical event/damage analysis • Empirical correlation model • Hazard and vulnerability analysis • Downscaling climate change scenarios in national level • R/S data based flood analysis model development • Hazard and vulnerability analysis update	• Downscaling climate change scenarios in local level • Advanced risk forecasting model development • Real-time risk hazard and vulnerability forecasting
Step III Understanding disaster risk	• Risk assessment framework • Risk zoning • Risk impact assessment • Climate change impact assessment in the field • Quantitative risk estimation	• Risk assessment on climate change adaptation • Real-time risk forecasting • Flood risk forecasting GIS mapping
Step IV Developing system for DRM	• Meteorological monitoring system • Climate change scenarios D/B system • R/S based monitoring system • Risk outlook • Social communication system	• Real-time forecasting system • Early warning system • Integrated flood information system
Step V Strengthening and enhancing DRM plan	• Review on existing strategies, policy, plans, laws and regulations • Flood risk education and training program • Establishing mid and long-term master plan • Risk governance and stakeholders cooperation • Risk mitigation and control plan	• Structural countermeasures plan • Non-structural countermeasure plan • Multi-hazard management plan • Emergency action plan

— Landslide

According to the survey, Indonesia is the most landslide disaster-prone country within the ASEAN member states. The landslide disaster awareness and preparedness for Indonesia is relatively high compared to the ASEAN countries. However, there were no respondents for the survey for Indonesia landslide disasters. However, based on paper research and regarding the conceptual framework for the landslide disasters research roadmap, Indonesia has completed the basic steps of data collection and risk analysis.

Weather and climate data, as landslide triggering data collection, has been performed and the landslide risk mapping is currently under process. According to the list of short-term priority items above, Indonesia is in need of accurate landslide forecasts and warning systems, as well as advanced real-time landslide forecasting model(s). More extended lead time for landslide early warning can be obtained by sub-seasonal forecasting model/system. Landslide risk estimation and GIS mapping are also urgent. Establishment of an effective and accurate early warning system and integrated landslide information system should be accomplished in the long-term, similar to the other ASEAN member states. Landslide risk perception, awareness, and educations are considered to be critical for successful DRM while cooperation among multi-stakeholders from local levels to international levels is considered for the long-term. As the survey emphasizes, enhancement of human resource capacity of landslide forecast is necessary for better landslide DRM in Indonesia.

— Typhoon

Impact of typhoons in the past 30 years is negligible in Indonesia. However, the south and south-eastern parts of Indonesia are known to be vulnerable to typhoon disasters since they lie in the track paths of cyclones originating in the southern Indian Oceana and Pacific Ocean. Development and/or improvement of typhoon monitoring systems and warning systems with people's perception changes for typhoon disaster risk are the most crucial. Impacts of global warming on typhoon risk in Indonesia need to be carefully considered.

Lao PDR

Country Demographics/Disasters Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Lao PDR	7,037,521	31	230,738	40.30%
Natural Disasters (EM-DAT, 2017)				
Disaster type	Event count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	4	-	750,000	1,000
Earthquake	-	-	-	-
Flood	19	153	3,907,011	153,878
Landslide	-	-	-	-
Tsunami	-	-	-	-
Typhoon	3	64	1,397,764	103,650
Volcano	-	-	-	-

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Drought

Although drought frequency is likely to increase across Lao PDR, drought risk reduction might not have been considered as a main component of the national disaster management framework, according to survey respondent comments. A major problem is limited human resources for drought analysis and risk assessment. Clearly, drought is a great concern in Lao PDR, given the ever-increasing CO2 concentration and temperatures. While the Department of Meteorology and Hydrology (DMH) is responsible for atmospheric observations and forecasting, drought analysis and assessment are not yet sufficient with the exception of a few drought susceptibility assessments from international organizations (e.g., UNDP) at mostly the provincial levels.

Many meteorological stations are available across Lao PDR. Using this gauging network, the DMH operates drought early warning systems. However, it is necessary to upgrade the manual gauging to automated data collection systems. Spatial coverage of automated gauges is insufficient. Developing education to enhance policy governance is encouraged through farmers' participation, given the high dependence of the Lao economy on agriculture. Table 22 provides the research agenda necessary for drought risk management in Lao PDR.

Table 22. Research agenda for drought risk management in Lao PDR

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Collecting meteorological data • Collecting geophysical and hydrological data	• Expanding data categories related to drought • Updating database and advancing quality control techniques
Step II Risk Analysis	• Analysis of drought occurrence and severity • Assessing spatial extent of droughts	• Establishing forecast-based risk analysis framework
Step III Understanding disaster risk	• Mapping drought risks in terms of hazard, exposure, and vulnerability • Assessing climate change impacts on drought risk	• Assessing drought hazard and vulnerability under forecasted climate conditions
Step IV Developing system for DRM	• Developing drought monitoring system • Archiving past drought events and their consequences	• Developing real-time forecasting and early warning system • Developing integrated multi-hazard detection systems
Step V Strengthening and enhancing DRM plan	• Developing drought risk education and training program • Developing policies for emergency response and relief	• Review on existing strategies, policy, plans, laws and regulations • Evaluating and revising drought mitigation plans periodically

— Flood/Inundation

Over the past decade, 19 floods have been recorded in Lao PDR, impacting more than 3.9 million people and resulting in 153 casualties and $ 153 million in damages (EM-DAT, 2017). The amount of damage in Lao PDR caused by floods in the last 10 years is reported as eighth among the ASEAN member states. This results from the fact that Lao PDR is a relatively flood-safe country when compared to the remainder of the region.

The following table shows the research roadmap for Lao PDR including short-term priority items and long-term items for DRR based on online and offline survey results.

Table 23. Research agenda for drought risk management in Lao PDR

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• In-situ test data • Disaster chain • Build up D/B system • D/B system update and advanced quality control • Geomorphological data setting	• Real-time meteorological data and R/S data collection • Seasonal Forecasting data
Step II Risk Analysis	• Empirical correlation model • Hazard and vulnerability analysis • Downscaling climate change scenarios in national level • R/S data based flood analysis model development • Advanced risk forecasting model development	• Real-time risk hazard and vulnerability forecasting • Seasonal Forecasting model • Downscaling climate change scenarios in local level
Step III Understanding disaster risk	• Risk assessment framework • Risk zoning • Risk impact assessment • Flood risk forecasting	• Quantitative risk estimation • GIS mapping of risk
Step IV Developing system for DRM	• Climate change scenarios D/B system • R/S based monitoring system • Social communication system • Integrated flood information system • Multi-hazard detection system	• Meteorological monitoring system • Annual report • Early warning system
Step V Strengthening and enhancing DRM plan	• Developing drought risk education and training program • Developing policies for emergency response and relief	• Review on existing strategies, policy, plans, laws and regulations • Evaluating and revising drought mitigation plans periodically

— Typhoon

Located inland of Indochina Peninsular, Lao PDR has typhoons very occasionally. Since most of the typhoons that made landfalls in the country originated in the western Pacific and South China Sea, typhoon intensity is usually weaker than that in Vietnam or the Philippines. Nevertheless, a destructive typhoon such as Ketsana, which hit Lao in the lean season right before the harvest period in 2009, served as a wake-up call in regards to the risks and impact fo typhoons, especially in regards to food security (Nambooze et al., 2013). Several factors can increase typhoon risk in Lao PDR: changes of typhoon tracks and intensity, global warming, population increase and economic growth, and fast urbanization and poverty. Under this situation, current/short-term DRM options in data collection (step I) and risk analysis (step II) described in the ideal typhoon research matrix (Figure 18) are preferentially suggested. Among them, development of typhoon monitoring systems and effective typhoon warning systems with people's perception changes for typhoon disaster risk are the most crucial. In particular, international and trans-boundary cooperation with countries involved can substantially enhance typhoon DRM in a short-term.

Malaysia

Country Demographics/Disasters Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Malaysia	31,164,177	95	328,390	75.20%
Natural Disasters (EM-DAT, 2017)				
Disaster type	Event count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	2	-	2,205,000	-
Earthquake	1	24	10	2
Flood	37	197	865,899	1,417,000
Landslide	5	168	291	-
Tsunami	1	80	5,063	500,000
Typhoon	2	272	6,291	53,000
Volcano	-	-	-	-

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Drought

Though droughts occur less frequently than floods in Malaysia, their impacts have been significant (e.g., nation-wide drought in 2014; Abdulah et al., 2014). The Malaysian Meteorological Department currently uses the SPI and precipitation anomaly, indicating that they currently have ongoing drought monitoring. Dam levels and river flows are also used for detecting hydrological drought. However, because the Malaysian government pays great attention to floods, exposure and vulnerability to drought have not been well evaluated. Forecast-based drought management seems to have low-priority for the stakeholders.

The survey results indicate that monitoring and collection of drought-related data are relatively good in Malaysia, while drought analysis and assessment need to be improved. The respondents were interested in climate change and the shifting socioeconomic conditions that will affect the severity and duration of future drought events. They also showed interests in promoting the governance of drought policies through educational programs. As long-term research topics, upgrading data category and quality, and forecast-based risk management were chosen. Improving the policy governance was also in their interests. Table 24 summarizes the high-priority research agenda for drought risk reduction in Malaysia.

Table 24. Research agenda for drought risk management in Malaysia

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Updating meteorological data and improving data quality • Collecting projections of socioeconomic conditions	• Updating socioeconomic and climate change scenarios • Updating database and advancing quality control techniques
Step II Risk Analysis	• Assessing resource inventory and identify groups at risk	• Assessing social resilience to drought impacts • Establishing forecast-based risk analysis framework
Step III Understanding disaster risk	• Assessing climate change impacts on drought risk	• Developing mitigation and adaptation plans under changing conditions • Assessing drought hazard and vulnerability under forecasted climate conditions
Step IV Developing system for DRM	• Developing drought monitoring system • Finding predictors of drought for early warning	• Developing real-time forecasting and early warning system • Developing integrated multi-hazard detection systems
Step V Strengthening and enhancing DRM plan	• Review on existing strategies, policy, plans, laws and regulations • Developing drought risk education and training program	• Developing regional drought policy frame-work • Evaluating and revising drought mitigation plans periodically

— Flood/Inundation

Over the past decade, 37 floods have been recorded in Malaysia resulting in more than 0.86 million impacted people with 197 casualties and $ 1.4 billion in damages (EM-DAT, 2017). The amount of damage in Malaysia caused by floods in the last 10 years is reported to be sixth in the ASEAN region, and the total casualties and affected people are ranked seventh among the ASEAN member states. Malaysia seems to be in relatively flood-safe locations that the other ASEAN members. Therefore, it is shown that flood DRM and management in Malaysia are not in high priority consideration in comparison to other disasters.

The following table shows the Malaysia research roadmap including short-term priority items and long-term items for DRR based on online and offline survey results.

Table 25. Research agenda for flood risk management in Malaysia

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• GIS/Land use Data collection • GIS/Sewer system data collection • Climate change data collection • Build up D/B system • D/B system update and advanced quality control	• Raw data service • Seasonal Forecasting data • Real-time meteorological data and R/S data collection • Climate change scenarios update • Geomorphological data setting • R/S data collection
Step II Risk Analysis	• Historical event/damage analysis • Empirical correlation model • Hazard and vulnerability analysis • Hazard and vulnerability analysis update	• Seasonal Forecasting model • Real-time risk hazard and vulnerability forecasting • Advanced risk forecasting model development • Downscaling climate change scenarios in local level
Step III Understanding disaster risk	• Risk assessment framework • Risk zoning • Risk impact assessment • Flood risk forecasting GIS mapping	• Risk seasonal forecasting • Real-time risk forecasting • Risk assessment on climate change adaptation • GIS mapping of risk
Step IV Developing system for DRM	• Meteorological monitoring system • Annual report • Social communication system • Integrated flood information system	• Early warning system • Risk outlook • R/S based monitoring system
Step V Strengthening and enhancing DRM plan	• Review on existing strategies, policy, plans, laws and regulations • Flood risk education and training program • Non-structural countermeasure plan • Multi-hazard management plan • Emergency action plan	• Structural countermeasures plan • Establishing mid and long-term master plan • Risk governance and stakeholders cooperation

— Landslide

According to the survey, Malaysia has already accomplished the basic data collection for landslide disasters (e.g., historical weather and climate data, in-situ data and climate change scenarios). It is understood that landslide-related triggering data is managed well in Malaysia compared to other ASEAN member states. Based on the survey results, one of the short-term priorities for step I was advanced data collection such as remote sensing data and climate change data, as well as its quality control and updating system was needed. And to build a database system for managing landslide-induced data was a long-term priority in Malaysia. In addition, regarding step II, most of the basic steps of risk analysis in national level (e.g., downscaling climate change scenarios and hazard and vulnerability analysis) were chosen as the short-term priority items. And development of the advanced landslide forecasting model(s) was urgent top-priority items, such as the development of a remote sensing based landslide analysis model and the build up of S2S and seasonal forecasts model.

In contrast, downscaling climate change scenarios to the local level and advanced forecasting models (e.g., real-time hazard and vulnerability forecasting, landslide service model) were considered to be longer term priority tasks in Malaysia. For understanding disaster risk in step III, landslide risk zoning and quantitative risk estimation have carried out as a short-term priority in Malaysia. The GIS mapping of landslide risk and risk forecasts are also required. The landslide rescue mapping and landslide prediction under climate change were determined as long-term priority.

For system development for DRM in step IV, monitoring on illegal logging and socio-economic damage analysis is appeared to be short-term priorities in Malaysia, followed by landslide annual reports and landslide seasonal outlook. Climate change scenarios D/B system, R/S based monitoring system and social communication system (e.g., Mass media, and Tele-communication) were long-term priorities. Also, the landslide early warning system and multi-hazard detection systems are considered to be longer term options. For strengthening and enhancing of DRM plans in step V, education and training, risk mitigation and control plan, non-structural measures plan, and diverse institutional and stakeholders cooperation are chosen as short-term priorities. And establishing mid- and long-term master plan, multi-hazard management plan, and landslide insurance are considered as a longer term options in Malaysia.

Based on the result of survey, items to be performed in short- and long-term priority options are listed in Malaysia:

Table 26. Research agenda for landslide risk management in Malaysia

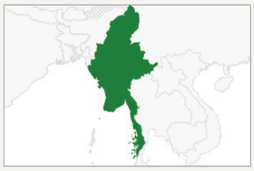
Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Landslide disaster chain • Climate change data collection • Data update and quality control • Geomorphological data setting • Remote sensing date collection • Real-time meteorological data collection	• Socio-economic data collection • Climate change scenarios update • Database system update and advanced quality control • Buildup database system • S2S and seasonal forecasting system • Raw data service
Step II Risk Analysis	• Downscaling climate change scenarios in national level • Remote sensing data based landslide analysis model • Landslide and vulnerability analysis in local level • Build up S2S, and seasonal forecasts model	• Downscaling climate change scenarios in local level • Developing advanced risk forecasting model • Forecasting real-time risk hazard and vulnerability • Developing landslide service model
Step III Understanding disaster risk	• Landslide risk assessment framework • Landslide risk zoning • Landslide risk impact assessment • Quantitative landslide risk estimation • GIS mapping by landslide risk forecasts • Landslide risk seasonal forecasting	• Climate change impact assessment in the field • landslide rescue mapping • landslide risk assessment under climate change • landslide risk forecasts using S2S • Risk assessment on climate change adaptation • Real-time landslide risk forecasting
Step IV Developing system for DRM	• Monitoring system on illegal logging • landslide risk annual report • landslide risk seasonal outlook • Socio-economic damage analysis system • Real-time forecast system and S/W development • Integrated information system and services (e.g., Homepage)	• Climate change scenarios D/B system • Remote sensing based monitoring system • Social communication system (e.g., Mass media, and Tele-communication) • Landslide early warning system • Multi-Hazard detection system
Step V Strengthening and enhancing DRM plan	• Landslide risk education and training program landslide risk annual report • Modify and Maintenance of landslide related laws system • Risk governance and stakeholders cooperation • Risk mitigation and control plan • Non-structural measures plan on landslide • Diverse institutional and multi-stakeholders cooperation	• Establishing Mid- and Long-term Master Plan • Multi-hazard management plan • Landslide insurance

— Typhoon

Malaysia is not located in the typhoon track paths in general, and the direct impact of typhoons on Malaysia is very rare. In one exceptional case, Vamei originated in the equatorial Pacific and then passed through the southern part of West Malaysia in 2001. This typhoon is responsible for 5 fatalities and 4.2 million USD dollars of economic damage. Since it is generally known that typhoons are generated in the off-equators, the Vamei's case implies such a near-equatorial typhoon may recur in the future.

In this case, lack of adequate observational and monitoring system for typhoon and the low level of public perception on typhoon risk are considered to be main challenges. Therefore, the development of typhoon monitoring systems and effective typhoon warning systems with people's perception changes for typhoon disaster risk can substantially enhance typhoon DRM in the short-term in Malaysia. In addition, local, state-level, governmental, and international cooperation for typhoon DRM also seems to be crucial.

Myanmar



Country Demographics/Disasters Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Myanmar	54,836,483	84	653,593	34.50%
Natural Disasters (EM-DAT, 2017)				
Disaster type	Event count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	-	-	-	-
Earthquake	5	116	24,075	14,770
Flood	22	622	3,536,342	257,655
Landslide	7	205	147,582	-
Tsunami	1	71	15,700	500,000
Typhoon	5	138,698	2,830,125	4,067,688
Volcano	-	-	-	-

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Flood/Inundation

Over the past decade, 22 floods have been recorded in Myanmar (EM-DAT, 2017), which is ranked the second in ASEAN region. As a result, more than 3.5 million people were affected, resulting in 622 casualties and $0.25 billion in damages. The amount of damage in Myanmar caused by floods in the last 10 years is reported seventh and total casualties and affected people are ranked sixth among ASEAN countries. This result from fact that Myanmar is relatively flood safe country in ASEAN members. Therefore, it reveals that flood DRM and management in Myanmar are not in high priority consideration compare with other disasters.

Next table shows research roadmap including short-term priority items and long-term items for Malaysia DRR based on online and offline literature reviews.

Table 27. Research agenda for flood risk management in Myanmar

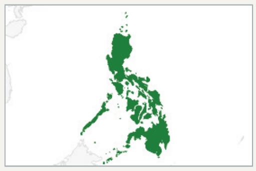
Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Flood triggering data • In-situ test data • Disaster chain • Data update and quality control • R/S data collection • Geomorphological data setting • Climate change scenarios update	• Climate change data collection • Build up D/B system • D/B system update and advanced quality control
Step II Risk Analysis	• Historical event/damage analysis • Empirical correlation model • Hazard and vulnerability analysis • Downscaling climate change scenarios in national level • R/S data based flood analysis model development • Hazard and vulnerability analysis update	• Downscaling climate change scenarios in local level • Advanced risk forecasting model development • Real-time risk hazard and vulnerability forecasting
Step III Understanding disaster risk	• Risk assessment framework • Risk zoning • Risk impact assessment • Climate change impact assessment in the field • Quantitative risk estimation	• Risk assessment on climate change adaptation • Real-time risk forecasting • Flood risk forecasting GIS mapping
Step IV Developing system for DRM	• Meteorological monitoring system • Climate change scenarios D/B system • R/S based monitoring system • Risk outlook • Social communication system	• Real-time forecasting system • Early warning system • Integrated flood information system
Step V Strengthening and enhancing DRM plan	• Review on existing strategies, policy, plans, laws and regulations • Flood risk education and training program • Establishing mid and long-term master plan • Risk governance and stakeholders cooperation • Risk mitigation and control plan	• Structural countermeasures plan • Non-structural countermeasure plan • Multi-hazard management plan • Emergency action plan

— Typhoon

Myanmar experiences typhoons occasionally, and had typhoons once every 6 years in the past 3 decades. Most of these typhoons originated in the Indian Ocean. Some of them are incredibly deadly cyclones such as Nargis. In early May 2008, Nargis made landfall in the southern coastal regions of Myanmar. The associated storm surge was up to 5 m with a wind speed of over 200 km/hour, causing catastrophic damage, e,g,. 138,000 casualties and hundreds of thousands homeless and vulnerable to injury and disease. Nargis brought to attention the DRM issues that need to be addressed, including the preparedness of a nation to handle a large scale crisis, public typhoon risk awareness, community empowerment, indigenous knowledge on typhoon risk, and risk impact (Fritz et al., 2009, Lateef 2009).

Several factors can increase typhoon risk in Myanmar: changes of typhoon tracks and intensity, global warming, population increase and economic growth, and fast urbanization and poverty. Under this situation, current/short-term DRM options in data collection (step I) and risk analysis (step II) described in the ideal typhoon research matrix (Figure 18) are suggested as priorities. Among them, development of typhoon monitoring systems and effective typhoon warning systems with people's perception changes about typhoon disaster risk are the most crucial. In particular, international and trans-boundary cooperation with related countries can substantially enhance typhoon DRM in the short-term.

Philippines



Country Demographics/Disasters Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Philippines	103,796,832	348	298,181	44.20%
Natural Disasters (EM-DAT, 2017)				
Disaster type	Event count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	6	8	4,038,069	148,852
Earthquake	15	2,871	5,552,800	441,401
Flood	120	2,280	26,926,207	3,527,402
Landslide	28	2,190	317,539	33,281
Tsunami	-	-	-	-
Typhoon	189	30,696	134,033,748	19,487,415
Volcano	16	719	1,576,258	216,282

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Flood/Inundation

Over the past decade, 120 floods have been recorded in the Philippines, the second highest in the ASEAN member countries (EM-DAT, 2017). As a result, more than 26 million people were affected, resulting in 2,280 casualties and $3.5 billion in damages. The amount of damage in the Philippines caused by floods in the last 10 years is reported number to be the fourth highest in the region, but is the second highest in event count among the ASEAN countries. This results from the fact that the Philippines is one of the most flood prone countries in the ASEAN region, but has well-prepared disaster management measures. The next table shows the research roadmap including short-term priority items and long-term items for Philippines DRR based on online and offline survey results.

Table 28. Research agenda for flood risk management in Philippines

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Climate change scenarios update • D/B system update and advanced quality control • Data update and quality control • Disaster chain • Climate change data collection	• Geomorphological data setting • Real-time meteorological data and R/S data collection • Seasonal Forecasting data • Raw data service
Step II Risk Analysis	• Empirical correlation model • Hazard and vulnerability analysis • Downscaling climate change scenarios in national level • R/S data based flood analysis model development	• Downscaling climate change scenarios in local level • Advanced risk forecasting model development • Real-time risk hazard and vulnerability forecasting • Seasonal Forecasting model
Step III Understanding disaster risk	• Risk zoning • Risk impact assessment • Climate change impact assessment in the field • Flood risk forecasting GIS mapping	• Risk assessment framework • Quantitative risk estimation • Risk assessment on climate change adaptation • Risk seasonal forecasting
Step IV Developing system for DRM	• Early warning system • R/S based monitoring system • Social communication system • Real-time forecasting system • Integrated flood information system	• Meteorological monitoring system • Annual report • Climate change scenarios D/B system • Risk outlook • Multi-hazard detection system
Step V Strengthening and enhancing DRM plan	• Establishing mid and long-term master plan • Risk governance and stakeholders cooperation • Non-structural countermeasure plan • Multi-hazard management plan • Risk mitigation and control plan • Emergency action plan	• Flood risk education and training program • Structural countermeasures plan

— Landslide

The Philippines experienced enormous property damage and both direct and indirect costs due to landslides, specifically rainfall-induced landslides caused by tropical storms (Saro, 2007; Ollet, 2008; and Zimmerli, 2009). According to the survey result, Philippines has not yet accomplished the basic data collection for landslide disasters (e.g., historical weather and climate data, in-situ data and climate change scenarios), and therefore this is strongly recommended. The other important task is monitoring the hydro-meteorological data, which is landslide triggering data, and performing landslide-related research for landslide monitoring. It was found that landslide-related data is not managed well in the Philippines where landslide disasters are mainly occurring among ASEAN countries. Therefore, one of the short-term priorities for step I is collecting GIS and soil data and remote sensing data collection for managing landslide-induced hydro-meteorological data, and the building of a database system and collecting climate change scenarios data are defined as long-term priorities in the Philippines. In addition, regarding step II, most of the basic steps of historical events and damage analysis and empirical correlation model(s) were chosen as the urgent top-priority items. And the landslide risk analysis (e.g., hazard and vulnerability analysis) was chosen as the short-term priority items. In contrast, the downscaling climate change scenarios and the development of landslide service model(s) were considered as the longer term priority task in Philippines. For understanding disaster risk in step III, quantitative landslide risk estimation, landslide rescue mapping, GIS mapping of landslide risk, and risk forecasts have been defined as short-term priorities in the Philippines. Landslide risk assessment under climate change was defined to be a long-term priority. For DRM system development, landslide early warning system appeared to be a short-term priority in Philippines, followed by real time R/S based monitoring system, and landslide seasonal outlook. Also the monitoring on illegal logging and social communication system (e.g., Mass media, and Tele-communication) development were defined as longer term priorities, followed by landslide annual report and socio-economic damage analysis. For strengthening and enhancing DRM plans in step V, establishing mid- and long-term master plans and modifying landslide-related law systems were chosen as short-term priorities, followed by non-structural measures, emergency action plans, and landslide insurance. For the long-term options in step V, the Philippines should pay attention to landslide risk awareness training and education and the governmental attempts to review and modify for maintenance of landslide-related policy and its law system for effective landslide DRM. Multi-hazard management plan and multi-stakeholders cooperation are required as well.

Based on the survey results, the items to be performed between short- and long-term options are listed below for the Philippines:

Table 29. Research agenda for landslide risk management in Philippines

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• GIS/Soil Data collection • Weather and climate data / Landslide triggering data • In-situ test data • Landslide disaster chain • Geomorphological data setting • Remote sensing data collection • S2S and seasonal forecasts data • Database system update and advanced quality control • Real-time meteorological data and remote sensing data collection • Raw data service and climate change impact assessment service	• Climate change data collection • Socio-economic data • Data update and quality control • Build up Database system • Cost effective sensors • Climate change scenarios update • S2S and seasonal forecast system
Step II Risk Analysis	• Historical event/damage analysis • Empirical correlation model • Landslide hazard and vulnerability analysis in national level • Remote sensing data based landslide analysis model development • Development of advanced landslide forecasting model • Real-time landslide hazard and vulnerability forecasting • S2S and seasonal forecasting model	• Downscaling climate change scenarios in national level • Landslide hazard and vulnerability analysis in local level • Downscaling climate change scenarios in local level • Landslide service model development
Step III Understanding disaster risk	• Quantitative Landslide risk estimation • Landslide rescue mapping • Landslide risk forecast using S2S • Real-time landslide risk forecasting • Landslide risk forecasting and GIS mapping • Landslide risk Seasonal Forecasting	• Climate change impact assessment in local level • Landslide risk assessment under climate change
Step IV Developing system for DRM	• Hydro-Meteorological monitoring system • Remote sensing based monitoring system • Landslide risk seasonal outlook • Socio-economic damage analysis • Real-time forecasting system and S/W development • Landslide early warning system • Multi-hazard detection system • Integrated landslide information system and service (Homepage)	• Monitoring on illegal logging • Landslide risk annual report • Climate change scenarios Database system • Social communication system (e.g., Mass media, Tele-communication)
Step V Strengthening and enhancing DRM plan	• Establishing Mid- and Long-term Master Plan • Modify and Maintenance of landslide related laws system • Non-structural measures plan on landslide • Emergency action plan • Landslide insurance	• Review on existing strategies, policy, plans, laws and regulations • Landslide risk education and training program • Risk governance and stakeholders cooperation • Structural measures plan on landside • Risk mitigation and control plan • Multi-hazard management plan • Diverse institutional and multi-stakeholders cooperation

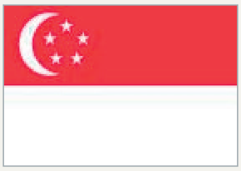
— Typhoon

The Philippines is one of the most typhoon disaster-prone countries. Accordingly, the typhoon disaster mitigation and awareness for the Philippines has greatly improved for the last decade. Basic steps of data collection and risk analysis have already been performed although they are still under process. According to the list of short-term priority items in Table 30, the Philippines is willing to step forward to quantitative DRM levels in making use of seasonal and sub-seasonal climate forecast data for typhoon DRM and developing advanced real-time typhoon forecasting model(s), typhoon storm surge model(s), and real-time typhoon risk model(s). Establishment of an effective and accurate early warning system and integrated typhoon information homepage should be accomplished in the short-term. Typhoon risk perception, awareness, and education are considered to be critical for successful DRM while cooperation among multi-stakeholders from local levels to international levels are sought for a long-term.

Table 30. Research agenda for typhoon (TP) risk management in Philippines

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Sub-seasonal weather forecasting data • D/B system update and advanced quality control • Sub-seasonal weather forecasting data • Seasonal climate forecasting data	• TP-related socio-economic data • TP-related health issues and data • Data update and quality control
Step II Risk Analysis	• Develop typhoon forecast models with data assimilation techniques and perform skill tests (real-time) • Develop effective typhoon warning systems • Typhoon storm surge modeling • Develop advanced TP forecasting model (real-time)	• Identify TP disaster chain • Downscaling of CC scenarios at national level • Improve sub-seasonal forecasting
Step III Understanding disaster risk	• TP risk with GIS mapping • Real-time TP risk forecasting • TP risk forecast with GIS mapping • Seasonal forecasting of TP risk	• TP risk assessment on climate change adaptation
Step IV Developing system for DRM	• Effective and accurate early warning systems • Integrated typhoon information system (homepage)	• Multi-hazard detection system • Coastal zone management • Crop and livestock protection • Establish effective networks and enhance public promotion
Step V Strengthening and enhancing DRM plan	• TP risk awareness, education, and training program • Enhance human resource capacity of TP forecast • International/trans-boundary cooperation • Survey on risk perception	• Review and change existing strategies, policy, plans, laws and regulations for TPs • Establish mid- and long-term master plan • Risk governance and stakeholders cooperation • Maintenance of TP related law system • Diverse institutional and multi-stakeholders cooperation • Enhance effectiveness and efficiency of the systems, cooperation, and communication

Singapore



Country Demographics/Disasters Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Singapore	5,784,538	8,264	700	N.A.
Natural Disasters (EM-DAT, 2017)				
Disaster type	Events count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	-	-	-	-
Earthquake	-	-	-	-
Flood	-	-	-	-
Landslide	-	-	-	-
Tsunami	-	-	-	-
Typhoon	-	-	-	-
Volcano	-	-	-	-

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Flood/Inundation

Singapore is an extraordinary country, being the only island not to record a natural flood disaster, reflecting its relatively low levels of exposure to physical risk and relatively high levels of economic development and infrastructural capacity (Pelling and Uitto, 2001). Therefore, Singapore has a Singapore Civil Defence Force (SCDF), which is a uniformed organisation under the purview of the Ministry of Home Affairs. The main role of SCDF is to provide fire-fighting, rescue, and emergency medical services; mitigating hazardous materials incidents; as well as to formulate, implement, and enforce regulations on fire safety and civil defence shelter matters.

— Typhoon

The impact of typhoons in the past 30 years is negligible in Singapore. However, typhoon risk cannot be ignored in Singapore. For example, typhoon Vamei passed through southern Malaysia, moving westward, and caused fatalities and substantial economic damage in Malaysia. In this circumstance, development and/or improvement of typhoon monitoring systems and warning systems with people's perception changes for typhoon disaster risk are to be most crucial. Impacts of global warming on typhoon risk in Singapore need to be carefully considered as well.

Thailand

Country Demographics/Disasters Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Thailand	68,297,547	134	510,827	51.00%
Natural Disasters (EM-DAT, 2017)				
Disaster type	Event count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	11	-	29,982,602	3,724,300
Earthquake	3	2	17,539	62,000
Flood	65	3,443	48,666,009	44,621,108
Landslide	3	47	43,110	-
Tsunami	1	8,345	67,007	1,000,000
Typhoon	18	819	3,816,896	744,823
Volcano	-	-	-	-

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Drought

The Weather Observation Bureau of the Meteorological Department monitors drought conditions with 123 meteorological stations, 35 river gauging stations, and 20 radar stations. In addition, weather and climate forecasts are available and thus possibly useful for agricultural and hydrological practices. At the national level, drought mitigation and response intervention plans have been prepared, which include cloud seeding, crop insurance, economic compensation for agricultural losses, and groundwater uses. The current drought risk management is well established for monitoring and evaluating meteorological, agricultural, and hydrological droughts. Perhaps, a remaining part to be considered in the current framework would be the socioeconomic conditions that may alter exposure and vulnerability to severe and extreme droughts. The survey results also indicate that gauging networks and monitoring systems are well established.

In the Surveys, collecting socioeconomic data and its projections was chosen as a short-term priority from the respondents. Linking local and national frameworks as well as developing educational programs, were also selected as short-term agendum. Currently, Thailand may focus on collecting socioeconomic data, upgrading relevant data and risk maps, and improving the framework governance of the disaster management framework. Developing multi-hazard detection systems was also selected as a short-term agendum. The items related to drought forecasts were likely to be considered as long-term issues. Table 31 summarizes the short-term and long-term research topics for Thailand.

Table 31. Research agenda for drought risk management in Thailand

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Collecting socioeconomic data • Updating meteorological data and improving data quality	• Updating socioeconomic and climate change scenarios • Updating database and advancing quality control techniques
Step II Risk Analysis	• Analysis of drought occurrence and severity • Assessing social resilience to drought impacts	• Establishing forecast-based risk analysis
Step III Understanding disaster risk	• Assessing risk of changing socioeconomic conditions	• Assessing risk of changing socioeconomic conditions
Step IV Developing system for DRM	• Developing integrated multi-hazard detection systems	• Developing real-time forecasting and early warning system
Step V Strengthening and enhancing DRM plan	• Developing drought risk education and training programs	• Evaluating and revising drought mitigation plans periodically

— Flood/Inundation

Over the past decade, 65 floods have been recorded in Thailand (EM-DAT, 2017). As a result, more than 40 million people were affected, resulting in 3,434 casualties and $ 44 billion in damages. The amount of damage in Thailand caused by floods in the last 10 years is reported to be the highest among the ASEAN member states. This results from the fact that Thailand is the most flood-prone country in the ASEAN region. Therefore, it reveals that flood DRM and management in Thailand is an incredibly urgent task.

Table 32 shows research roadmap including short-term priority items and long-term items for Thailand DRR based on online and offline survey results.

Table 32. Research agenda for flood risk management in Thailand

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• GIS/Land use Data collection • In-situ test data • Disaster chain • Build up D/B system • Climate change scenarios update • Raw data service	• GIS/Sewer system data collection • D/B system update and advanced quality control • Data update and quality control • R/S data collection • Geomorphological data setting
Step II Risk Analysis	• Historical event/damage analysis • Empirical correlation model • Hazard and vulnerability analysis • R/S data based flood analysis model development • Hazard and vulnerability analysis update	• Downscaling climate change scenarios in national level • R/S data based flood analysis model development • Real-time risk hazard and vulnerability forecasting • Seasonal Forecasting model
Step III Understanding disaster risk	• Risk assessment framework • Risk zoning • Quantitative risk estimation • GIS mapping of risk	• Climate change impact assessment in the field • Real-time risk forecasting • Flood risk forecasting GIS mapping • Risk seasonal forecasting
Step IV Developing system for DRM	• Meteorological monitoring system • Climate change scenarios D/B system • Social communication system • Real-time forecasting system	• R/S based monitoring system • Risk outlook • Early warning system • Integrated flood information system
Step V Strengthening and enhancing DRM plan	• Review on existing strategies, policy, plans, laws and regulations • Flood risk education and training program • Establishing mid and long-term master plan • Risk governance and stakeholders cooperation • Structural countermeasures plan	• Non-structural countermeasure plan • Multi-hazard management plan • Risk mitigation and control plan

— Typhoon

Among the typhoons affecting Thailand, those originating in the southeastern Sea of Philippines are more destructive than those originating in the lower latitudes (Vongvisessomjai 2009). Therefore, the northeastern part of Thailand is more often damaged by strong winds, storm surge, and heavy rain associated with typhoons.

From the typhoon survey results (Table 33), it was found that the basic steps of data collection (step I) has been started, while basic and fundamental steps of rsk analysis (step II) were selected to be the top priority items. The short-term priority items in Table 33 indicate that GIS mapping data, and TP-related socio-economic and health data, are immediately required and that the D/B system also needs to be built. Regarding step II, the top-priority items include 1) analysis and mapping of historical events/damages using GIS, analysis and mapping of typhoon hazards and vulnerability, and risk analysis for urban and rural areas. For step III, the development of a typhoon forecast model with reliable accuracy and an effective warning system are necessary. Understanding typhoon risk (e.g., relations with key climate variability) and impact assessments are also essential.

Regarding DRM (step VI and step V), establishment of an effective and accurate early warning system and integrated typhoon information homepage should be accomplished in a short-term as other ASEAN countries require. In Thailand, review and change of exiting strategies, policy, plans, laws, and regulations for typhoons and implementation of guidelines were selected as short-term priority items. On the other hand, typhoon risk perception, awareness, and education as well as cooperation among multi-stakeholders from local levels to international levels are suggested as long-term research items.

Table 33. Research agenda for Typhoon (TP) risk management in Thailand

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• GIS mapping data • Typhoon-related socio-economic data • Typhoon-related health issues and data • Build up D/B system	• Seasonal climate forecasting data • Climate change scenarios update
Step II Risk Analysis	• Analyze and map historical events/damages using GIS •Analyze and map typhoon hazards and vulnerability • Risk analysis for urban and rural areas • Develop typhoon forecast models with data assimilation techniques and perform skill tests (real-time) • Develop effective typhoon warning systems	• Improve data assimilation technique • Improve accuracy of TP forecast and warning system • Develop TP subseasonal forecasting • Improve sub-seasonal forecasting
Step III Understanding disaster risk	• Typhoon risk impact assessment • Identify causes of typhoon-related loss of life (e.g., location, gender, social status etc.) • Study/understand impacts of Madden-Julian Oscillation (MJO)/ Boreal Summer Intraseasonal Oscillation (BSISO), decadal changes, and climate change on typhoons • Quantitative typhoon risk estimation	• Real-time TP risk forecasting • TP risk forecast with GIS mapping • Seasonal forecasting of TP risk
Step IV Developing system for DRM	• TP annual report • Effective and accurate early warning systems • Provide seasonal typhoon outlooks • Integrated typhoon information system (homepage) • Multi-hazard detection system	• Coastal zone management • Crop and livestock protection • Establish effective networks and enhance public promotion • Structural mitigation measures (e.g., shelters, roads, canals, and drains)
Step V Strengthening and enhancing DRM plan	• Review and change existing strategies, policy, plans, laws and regulations for typhoons • Implementation of guidelines • Emergency action plan	• TP risk awareness, education, and training program • Risk governance and stakeholders cooperation • Enhance human resource capacity of TP forecast • Diverse institutional and multi-stakeholders cooperation • Enhance effectiveness and efficiency of the systems, cooperation, and communication

Viet Nam

Country Demographics/Disasters Statistics

Country Demographics	Population -2017	Density (P/Km²)	Land Area (Km²)	Urban Population (%)
Viet Nam	95,414,640	308	310,090	33.80%
Natural Disasters (EM-DAT, 2017)				
Disaster type	Event count	Total deaths (persons)	Total affected (persons)	Total damage (1000 USD)
Drought	6	-	7,860,000	7,399,120
Earthquake	-	-	-	-
Flood	72	4,624	24,873,245	4,111,507
Landslide	6	330	39,074	2,300
Tsunami	-	-	-	-
Typhoon	68	7,976	25,443,955	6,697,857
Volcano	-	-	-	-

Source: Worldmeters (http://www.worldemters.infor), EM-DAT (http://www.emdat.be/)

— Drought

Drought is a frequent natural disaster in Viet Nam, which occurred 40 times during the last 50 years (UN Water, 2014). The highly variable monsoon season significantly affected by ENSO is a major cause. The most drought-prone area is in the southern Vietnam, suffering from a lack of irrigation infrastructure and water management systems (UN Water 2014). Due to frequent drought episodes, drought monitoring and early warning systems have been improved by the National Centre for Hydro-Meteorological Forecasting and the Vietnam Institute of Meteorology, Hydrology and Environment. Meteorological stations are densely installed across Vietnam, thus data collection and monitoring are relatively sufficient. Weather and climate forecasts are likely being used for some hydrological and agricultural practices.

According to the survey, high-priority research agenda include collection of socioeconomic data and projections, drought severity and frequency analyses, mapping exposure and vulnerability to drought, finding drought predictors, and establishing local drought risk management framework. It was indicated that the respondents were interested in risk assessment and forecasting, and socioeconomic conditions. As long-term agenda, expanding data categories, assessing further impacts on society and forecast-based drought risk management were selected. Table 34 is the research agenda for Vietnam based on the survey.

Table 34. Research agenda for drought risk management in Viet Nam

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Collecting socioeconomic data • Collecting projections of socioeconomic conditions	• Expanding data categories related to drought
Step II Risk Analysis	• Analysis of drought occurrence and severity	• Assessing further impacts of drought on societies
Step III Understanding disaster risk	• Assessing risk of changing socioeconomic conditions	• Assessing drought hazard and vulnerability under forecasted climate conditions
Step IV Developing system for DRM	• Finding predictors of drought for early warning	• Developing real-time forecasting and early warning system
Step V Strengthening and enhancing DRM plan	• Establishing local drought policy framework	• Developing and publicizing national drought policy frameworks

— Flood/Inundation

Over the past decade, 72 floods have been recorded in Viet Nam (EM-DAT, 2017). As a result, more than 24 million people were affected, resulting in 4,624 casualties and $4.1 billion in damages. The amount of damage in Viet Nam caused by floods in the last 10 years is reported as third among the ASEAN member states, but the number of deaths (third) is relatively large compared to the effected people (fifth) among ASEAN countries. This results from the fact that numerous people in Viet Nam are living flood prone areas, but measures to mitigate the damage are not relatively well prepared.

Next table shows research roadmap including short-term priority items and long-term items for Thailand DRR based on online and offline survey results.

Table 35. Research agenda for flood risk management in Viet Nam

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Flood triggering data • Disaster chain • D/B system update and advanced quality control • Data update and quality control • R/S data collection • Geomorphological data setting • Real-time meteorological data and R/S data collection • Seasonal Forecasting data • Raw data service	• GIS/Land use Data collection • GIS/Sewer system data collection • In-situ test data • Climate change data collection • Build up D/B system • Climate change scenarios update
Step II Risk Analysis	• Historical event/damage analysis • Empirical correlation model • Hazard and vulnerability analysis • Advanced risk forecasting model development • Seasonal Forecasting model	• Downscaling climate change scenarios in national level • R/S data based flood analysis model development • Hazard and vulnerability analysis update • Downscaling climate change scenarios in local level
Step III Understanding disaster risk	• Risk zoning • Risk impact assessment • Real-time risk forecasting • Flood risk forecasting GIS mapping • Risk seasonal forecasting	• Climate change impact assessment in the field • Quantitative risk estimation • Risk assessment on climate change adaptation
Step IV Developing system for DRM	• R/S based monitoring system • Risk outlook • Social communication system • Real-time forecasting system	• Annual report • Climate change scenarios D/B system • Early warning system • Integrated flood information system
Step V Strengthening and enhancing DRM plan	• Review on existing strategies, policy, plans, laws and regulations • Flood risk education and training program • Establishing mid and long-term master plan • Risk governance and stakeholders cooperation	• Structural countermeasures plan • Non-structural countermeasure plan • Multi-hazard management plan • Risk mitigation and control plan • Emergency action plan

— Landslide

With the natural conditions in Vietnam, landslide hazards occur annually, covering all the places from high lands to delta and coastline areas, killing a significant number of people and damaging properties in Viet Nam (Nguyen, 2012). The number of landslide-induced deaths in Viet Nam was reported to be 130 persons in the year 2007, with an average of 2.9 deaths per landslide (Maria et al., 2010). According to the survey, Vietnam has already accomplished the basic data collection for landslide disaster (e.g., historical weather and climate data, in-situ data and climate change scenarios). Surveys indicated that landslide-related triggering data is managed well in Viet Nam when compared to other ASEAN countries. Based on the survey results, one of the short-term priorities for step I was landslide-related data collection (e.g., climate change data, remote sensing data), and its quality control and developing D/B system appeared to be top priority options. S2S, seasonal forecasts, and climate change scenario data updates in different time scale were considered as a long-term priority in Vietnam. Regarding step II, the development of remote sensing based landslide analysis model and most of the basic steps of risk analysis on the local level (e.g., hazard and vulnerability analysis, downscaling climate change scenarios) were chosen as the short-term priority items. Development of S2S and seasonal forecasts model(s) and the development of the landslide service model were long-term items in Vietnam.

For understanding disaster risk in step III, landslide risk GIS mapping and landslide rescue mapping have been defined as a short-term priority in Vietnam. And the real-time landslide forecasting and landslide risk forecasting were considered as long-term priorities. For system development for DRM in step IV, remote sensing based monitoring system was determined as a short-term priority in Vietnam, and followed by socio-economic damage analysis and social communication system (e.g., Mass media, and Tele-communication). The landslide early warning system and multi-hazard detection systems are also considered as short-term items. The landslide seasonal outlook and real-time forecasting system were determined as long-term priorities, followed by integrated landslide information system (e.g., homepage). For strengthening and enhancing of DRM plans in step V, establishing mid- and long-term master plan and modifying law systems were chosen as short-term priorities. Moreover, the risk mitigation plans, multi-hazard management plans, and emergency action plans were considered as short-term priorities. The multi-stakeholder cooperation and landslide insurance were considered as longer term options in Viet Nam.

Based on the result of survey, items to be performed between short- and long-term options are listed in Viet Nam in Table 36.

Table 36. Research agenda for landslide risk management in Viet Nam

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Landslide disaster chain • Climate change data collection • Socio-economic data • Data update and quality control • Build up Database system • Cost effective sensors • Geomorphological data setting • Remote sensing data collection	• S2S and seasonal forecasts data • Climate change scenarios update • Database system update and advanced quality control • Real-time meteorological data and remote sensing data collection • S2S and seasonal Forecast system • Raw data service and climate change impact assessment service
Step II Risk Analysis	• Remote sensing data based landslide analysis model development • Landslide hazard and vulnerability analysis in local level • Downscaling climate change scenarios in local level • Development of advanced landslide forecasting model	• Real-time landslide hazard and vulnerability forecasting • S2S and seasonal Forecasting model • Landslide service model development
Step III Understanding disaster risk	• Climate change impact assessment in local level • Landslide risk GIS mapping • Landslide rescue mapping • Landslide risk forecast using S2S	• Real-time landslide risk forecasting • Landslide risk forecasting and GIS mapping • Landslide risk seasonal forecasting
Step IV Developing system for DRM	• Remote sensing based monitoring system • Socio-economic damage analysis • Social communication system (e.g., Mass media, Tele-communication) • Landslide early warning system • Multi-hazard detection system	• Landslide risk seasonal outlook • Real-time forecasting system and S/W development • Integrated landslide information system and service (e.g., Homepage)
Step V Strengthening and enhancing DRM plan	• Establishing Mid- and Long-term Master Plan • Modify and Maintenance of landslide related laws system • Risk governance and stakeholders cooperation • Risk mitigation and control plan • Multi-hazard management plan • Non-structural measures plan on landslide • Emergency action plan	• Diverse institutional and multi-stakeholders cooperation • Landslide insurance

— Typhoon

Vietnam is located in the Southeast Asian typhoon belt and the northeastern coastal regions of Vietnam are often damaged by strong winds, storm surge, and heavy rain associated with typhoons. Therefore, typhoon disaster awareness and perception for Vietnam are relatively good. The survey results of Vietnam are similar to those of the Philippines: basic steps of data collection and risk analysis have been performed, although they are still under process. According to the list of short-term priority items (Table 37), Viet Nam is in need of accurate typhoon forecast and warning systems as well as advanced real-time typhoon forecasting model(s). More extended lead time for early warning can be obtained by sub-seasonal forecasting model/systems. Typhoon risk estimation and GIS mapping are also urgent. Establishment of an effective and accurate early warning system and integrated typhoon information homepage should be accomplished in the short-term, similar to other ASEAN member states. Typhoon risk perception, awareness, and education are considered to be critical for successful DRM while cooperation among multi-stakeholders from local levels to international levels are sought for the long-term. Viet Nam is found to experience more typhoons in the recent three decades and their paths changed unexpectedly. As the survey emphasizes, enhancement of human resource capacity of typhoon forecast is necessary for better typhoon DRM in Viet Nam.

Table 37. Research agenda for typhoon (TP) risk management in Viet Nam

Steps	Short-term agenda	Long-term agenda
Step I Data collection	• Data update and quality control • Subseasonal weather forecasting data • D/B system update and advanced quality control • Seasonal climate forecasting data • Climate change scenarios update	•(N/A)
Step II Risk Analysis	• Improve accuracy of TP forecast and warning system • TP hazard and vulnerability analysis update • Develop advanced TP forecasting model (real-time) • Develop TP subseasonal forecasting • Real-time TP hazard and vulnerability forecasting • Downscaling of climate change scenarios	• Local-scale risk assessment • Improve data assimilation techniques • Improve sub-seasonal forecasting
Step III Understanding disaster risk	• Quantitative TP risk estimation • TP risk with GIS mapping • TP risk forecast with GIS mapping • Seasonal forecasting of TP risk	• Identify causes of TP-related loss of life (e.g., location, gender, social status etc.)
Step IV Developing system for DRM	• Establish effective networks and enhance public promotion • Effective and accurate early warning systems • TP outlook • Building design and construction changes • Integrated typhoon information system (homepage)	• Multi-hazard detection system • Structural mitigation measures (e.g., shelters, roads, canalsv, and drains)
Step V Strengthening and enhancing DRM plan	• Implementation of guidelines • TP risk awareness, education, and training program • Enhance human resource capacity of TP forecast • Maintenance of TP related law system	• Risk governance and stakeholders cooperation • Establishing local TP policy framework • Multi-hazard management plan • Explore beneficial use of TP-related resources • Diverse institutional and multi-stakeholders cooperation • Enhance effectiveness and efficiency of the systems, cooperation, and communication

Concluding Remarks

Concluding Remarks

The following conclusions are worth emphasizing for science-based DRM in the ASEAN region:

— Meteorological data collection, which is a fundamental component for proactive DRM, has improved significantly across the ASEAN region. Particularly, meteorological gauging networks are becoming denser in Indonesia, Vietnam, and Thailand through national financing and/or internationally funded projects. However, there may be a need for reconstructing past meteorological observations for reliable analysis and assessment of disaster risk. Meteorological observations are a basis for estimation of hazards, exposure, and vulnerability to disasters. In fact, global datasets, that are somewhat extensive, are currently available for some disasters (e.g., drought and flood), and thus can be applied to the DRM framework. If there is capacity to handle high-dimensional datasets, data reconstruction and risk mapping would be currently possible for all the ASEAN region. Natural disasters are usually recurrent because of natural oscillations, such as ENSO. Since characterizing temporal and spatial patterns of natural disasters is a basis of DRM, collecting freely available data would be beneficial (e.g., reanalyzed climatology and remote-sensing based datasets). Establishing and expanding gauging networks is not the only option for meteorological data collections.

— Past activities in developing and improving DRM in the ASEAN region have been focused on data collection, disaster risk analysis, and risk and hazard mapping. One of the critical steps to follow in DRM is the development of timely and effective early warning system for each disaster or multi-disasters. In the best practice cases, early warning systems depend on reliable forecast models. In fact, several countries in ASEAN operate numerical forecasting models for early warning, mostly for floods and typhoons. However, landslide models are rarely found. In the survey, one of the top priority items across the disaster types was a development of real-time forecast models. This finding implies a high demand for quantitative DRM methods in the ASEAN region. Statistical models can also predict floods and droughts with relatively low costs, as long as suitable predictors are available. In order to develop statistical models, they require scientific investigations on not only the physical mechanisms of the disasters, but also valuable predictors. Meanwhile, the survey results also emphasize the needs of seasonal/sub-seasonal predictions and outlooks of hydrological disasters (e.g., floods, droughts, and typhoons) for better preparedness and early warning. These demands can be met by utilizing seasonal/sub-seasonal climate predictions on temperatures and precipitation produced by state-of-art climate models.

— In the context of global climate change, natural disasters are becoming one of the largest challenges facing the ASEAN region due to their increasing rate and frequency, as well as the magnitude of hazards around the world. Furthermore, the spatial and temporal scale of disasters in the ASEAN region is also rapidly increasing in the context of regional societal change. Disaster risk reduction, which combines disaster risk science and its integrated management as well as the reducing of variations, is a very important factor between the physical environment and socio-economic conditions in the ASEAN region both on a spatial-temporal scale as well as mid- and long-term priorities. For successful DRR/DRM in ASEAN countries, systematic DRM efforts based on scientific evidence is the most important, indicating the importance of decreasing the uncertainty level in science, technology, and management. Finally, there is a need to conduct customized DRM policies and research for each ASEAN country, in accordance with the HFA and SFDRR. In addition, for strengthening and enhancing DRR/DRM, international cooperation between ASEAN countries, governments, and institutions is important, and it is also necessary to establish cooperative relations with local communities.

- It should be noted that monitoring systems for disasters related to typhoons, floods, and landslides have already been established and are in operation. Research on DRR and DRM should be done sequentially from basic data collection to monitoring and forecasting. However, in the ASEAN region, a monitoring system using state-of-the-art satellites is already operated for rainfall observations, while flood forecasting is conducted with conventional empirical relations. This malformation structure leads to the inefficiency of data utilization. State-of-the-art monitoring systems can be constructed simply through the application of technology, but experts in the area are essential to the utilization of the results.

- Many of the agencies that responded to the surveys commonly stated that there is a lack of an education that trains professionals in the field of disaster management. Capacity building in disaster management would not only increase the country's research capacity, but also improve the current imbalanced research environment. Therefore, we would like to stress the importance of nurturing and utilizing local disaster experts, who are the most familiar with the unique environments of a particular country.

References
Appendix A. List of ASEAN
Research Resources

References

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Appendix A. List of ASEAN Research Resources

— ICRM (Institute of Catastrophe Risk Management, Nanyang Technological University, Singapore)

• URL: http://icrm.ntu.edu.sg/Pages/Home.aspx

• Description

ICRM is the first multi-disciplinary risk management research institute of its kind in Asia and amongst a handful of such centres in the world, which undertakes projects in science, engineering, finance, technology, economics and socio-political aspects related to catastrophe risk.

— BMKG (Badan Meteorologi, Klimatologi, dan Geofisika)

• URL: http://www.bmkg.go.id/

• Description

BMKG is a scientific organization that carries out the Indonesian government's tasks related to meteorology, climatology, and geophysics. Among its numerous mandates are to formulate and coordinate the execution of public policies, plans, and programs based on up-to-date scientific knowledge and research.

— PHIVOLCS (Philippine Institute of Volcanology and Seismology)

• URL: http://www.phivolcs.dost.gov.ph/

• Description

PHIVOLCS is the Philippines' national institution mandated to formulate up-to-date and comprehensive disaster preparedness and risk reduction action plans for volcanic eruption, earthquake occurrences, and related geotectonic processes.

— PDC (Pacific Disaster Center)

• URL: http://www.pdc.org/

• Description

The PDC works to foster disaster resilience through the use of applied science, information, and technology for sound, evidence-based decision making. The primary objectives of PDC are the following: (1) facilitate dialogue to develop understanding, (2) review progress on recent and ongoing landslide risks reduction initiatives and related research, (3) come up with recommendations and share similar lessons in the international community, and (4) identify research priorities and information / information management needs.

— PRiMO (Pacific Risk Management Ohana)

• URL: https://coast.noaa.gov/primo/

• Description

PRiMO began in 2002 as an effort to simply explore opportunities to enhance communication and collaboration among the ohana, or family, of local, national, and regional agencies, institutions, and organizations involved in DRR work. It is committed to enhancing the resilience of communities in the Pacific region.

PRiMO has since transformed into a collaborative effort governed by a coordinating council of 'navigators.' These key representatives from the region provide leadership, resources, and policy guidance as well as institutional support for PRiMO from within their respective organizations. The navigators are divided into working groups (huis) that provide a platform to encourage coordination and collaboration in the Pacific region to more effectively leverage resources and positively impact activity outcomes. PRiMO supports coordination in many forms including hosting meetings each year, facilitating technical working groups, supporting partnerships, and maintaining an online resource library, forum, and email list serve.

— IRDR (Integrated Research on Disaster Reduction)

• URL: http://www.irdrinternational.org

• Description

IRDR (Integrated Research on Disaster Reduction) is a multi-disciplinary research programme co-sponsored by the International Council for Science (ICSU), the International Social Science Council (ISSC), and the United Nations International Strategy for Disaster Reduction (UNISDR).

The mission of the programme is to develop trans-disciplinary and multi-sectorial alliances for in-depth and practical disaster risk reduction research studies as well as the implementation of effective evidence-based disaster risk policies and practices. It pursues an integrated approach to natural and human-induced environmental hazards through a combination of natural, socio-economic, health and engineering sciences, including socio- economic analysis, understanding the role of communications, and public and political response to reduce the risk.

The research objectives of the programme are to characterise hazards, vulnerability, and risk; to understand decision-making in complex and changing risk contexts; and to reduce risk as well as to curb losses through knowledge-based actions. Research programmes of IRDR are implemented by research working groups listed below, and the products of the programme include knowledge products of assessment results, guidelines, forums, research programmes developed, etc.

- AIRDR (Assessment of Integrated Research on Disaster Risk);
- DATA (Disaster Loss Data);
- FORIN (Forensic Investigations of Disasters);
- RIA (Risk Interpretation and Action); and
- SERA (Societal and Economic Research and Applications)

The research initiatives are supported and supplemented by National Committees (NCs), Regional Committees (RCs), and International Centres of Excellence (ICoE).

— ADPC (Asian Disaster Preparedness Center)

• URL: http://www.adpc.net/igo/

• Description

ADPC (Asian Disaster Preparedness Center) is a non-governmental regional organization providing technical assistance and support in disaster risk reduction to the countries including Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Lao PDR, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Saudi-Arabia, Sri Lanka, Thailand, the Philippines, and Vietnam based on the countries' needs.

The mission of ADPC is to reduce disasters and climate risk impacts on communities and countries in Asia-Pacific Region by working with governments, development partners and key stakeholders. ADPC aims to enhance capacity of countries in the utilization of science-based information to understand risk, to strengthen systems for effective management of risk at all levels in countries especially at sub-national and local level, and to improve grounded application of risk reduction measures in development.

ADPC deploys disaster risk management (DRM) information and systems to reduce local, national and regional risk across Asia-Pacific. Its portfolio focuses on DRM capacity building, improving DRM for cities and climate change, mainstreaming DRM into national and local development, improving DRM systems and undertaking disaster risk assessments. To achieve its aims in disaster risk reduction, ADPC works closely with local, national and regional governments, governmental and non-governmental organizations, donors and development partners.

ADPC's products can be divided into three categories according to their three core programs – science, systems, and applications. From the Science Program, their knowledge products include climate downscaling to local scales for emergency planning, the use of remote sensing and geographic information system to identify risks, and economic modelling for risk financing. Their Systems Program provides products in the form of the institutionalization and strengthening of disaster risk reduction systems. Integrating disaster risk reduction into development planning processes by applying the scientific knowledge is being done by the Application Program.

— ADRC (Asian Disaster Reduction Center)

• URL: http://www.adrc.asia

• Description

The Asian Disaster Reduction Center was established in Kobe, Hyogo prefecture, in 1998, with mission to enhance disaster resilience of the member countries, to build safe communities, and to create a society where sustainable development is possible. The Center works to build disaster resilient communities and to establish networks among countries through many programs including personnel exchanges in this field. There are 30 member countries including 9 of the 10 ASEAN countries except Brunei.

The Center addresses the above issue from a global perspective in cooperation with a variety of UN agencies and international organisations/initiatives, such as the International Strategy for Disaster Reduction (ISDR), the Office for the Coordination of Humanitarian Affairs (OCHA), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), the World Meteorological Organization (WMO), and the World Health Organization Regional Office for the Western Pacific (WHO/WPRO).

One of their main activities is information sharing on disaster reduction, which includes:
- Provision of information on the latest disasters, disaster preparedness of member countries, and good practice
  ▲Through their website (http://www.adrc.asia/disaster/index.php), ADRC provides information on the latest disasters, disaster management, and good practices for DRR. They also provide country reports for member states.
- Global Unique Disaster Identifier (GLIDE)
  ▲GLIDE is a unique identification scheme for disaster events proposed by ADRC, which composed of hazard code, year, serial number, and ISO country code.
- Disaster management support system (Sentinel Asia Project)
  ▲Sentinel Asia Project was launched in 2006 for disaster risk management in Asia. Disaster Management Support System (https://sentinel.tksc.jaxa.jp/sentinel2/topControl.jsp), which is a part of the project, provides emergency observation information based on earth satellites in the form of maps and satellite images to member countries. ADRC also works for human resources development by organizing conferences, workshops, and training on DRR and programs for inviting visiting researchers from member countries.

Building communities capabilities is also one of ADRC's main activities and ADRC develops and disseminates tools for encouraging community participation. ADRC undertakes various efforts including increasing public awareness of disaster risk management, and development and dissemination of tools for reducing vulnerability of communities.

— GAR (Global Assessment Report) on Disaster Risk Reduction 2015

- URL: https://www.unisdr.org/we/inform/gar
- URL for GAR15:
http://www.preventionweb.net/english/hyogo/gar/2015/en/home/index.html
- Description

The GAR is a comprehensive review and analysis of disaster risk and risk management published every two years. The GAR contributes to achieving the Hyogo Framework of Action (HFA) through monitoring risk patterns and trends and progress in disaster risk reduction while providing strategic policy guidance to countries and the international community. The GAR aims to focus international attention on the issue of disaster risk and encourage political and economic support for disaster risk reduction.

The Report is produced in collaboration and consultation with a wide range of stakeholders, including various UN agencies, governments, academic and research institutions, donors and technical organizations and specialists. The preparation of the GAR is coordinated and supervised by UNISDR.

The GAR Advisory Board acts as an independent and strategic advisory body to the SRSG (Special Representative of the Secretary-General for DRR) and UNISDR on the overall direction, political relevance and academic rigour of the GAR work streams. The Board members provide advice to the SRSG and GAR team on the concept and substantive content of each GAR as well as its dissemination to inform global processes on sustainable development and climate change adaptation.

The GAR Advisory Bard's members are appointed on the basis of their personal capacity rather than their institutional affiliation yet represent a broad spectrum of UNISDR partners, including representatives from science, governments, UN country representatives, civil society and private sector. Membership is usually for 4 years with a rotating system that allow for continuity over the report's biennial cycles.

UNISDR Regional Office for Asia-Pacific (http://www.unisdr.org/asiapacific)

- The UNISDR Regional Office for Asia and the Pacific is one of the six UNISDR secretariat Regional Offices, covering 27 countries and 16 territories.
- It has sub-regional offices in Suva, Fiji for the Pacific and a liaison office in Kobe, Japan. The Asia Pacific Regional Office supports on-going disaster risk reducing actions of people, governments, United Nations Country Teams, regional and international organizations, and the many stakeholders exposed to various hazards and risks.

— RIMES (Regional Integrated Multi-Hazard Early Warning System for Africa and Asia)

• URL: http://www.rimes.int/

• Description

RIMES is an international and intergovernmental institution, owned and managed by its Member States, for the generation and application of early warning information. RIMES evolved from the efforts of countries in Africa and Asia, in the aftermath of the 2004 Indian Ocean tsunami, to establish a regional early warning system within a multi-hazard framework for the generation and communication of early warning information, and capacity building for preparedness and response to trans-boundary hazards. RIMES was established on 30 April 2009, and was registered with the United Nations on 1 July 2009. RIMES operates from its regional early warning center located at the campus of the Asian Institute of Technology in Pathumthani, Thailand.

RIMES aims to provide regional early warning services and builds capacity of its Member States in the end-to-end early warning of tsunami and hydro- meteorological hazards. Its missions include building capacity and providing actionable warning information towards forearmed, forewarned and resilient communities.

There are 12 member states including Bangladesh, Cambodia, Comoros, India, Lao PDR, Maldives, Mongolia, Papua New Guinea, Philippines, Seychelles, Sri Lanka and Timor-Leste. 19 Collaborating Countries: Afghanistan, Armenia, Bhutan, China, Indonesia, Kenya, Madagascar, Mauritius, Mozambique, Myanmar, Nepal, Pakistan, Russian Federation, Somalia, Tanzania, Thailand, Uzbekistan, Vietnam, and Yemen.

RIMES caters to differential needs and demands of its Member States by enhancing capacities for end-to-end multi-hazard early warning, in particular:

- Hazard monitoring, detection, analysis, prediction, and forecasting
- Risk assessment
- Potential impact analysis
- Generation of tailored risk information at different time scales
- Risk communication
- Application of tailored risk information in decision-making

Key products of RIMES are as below:

- Earthquake & tsunami watch
  - ▲Earthquake information, tsunami bulletins, tsunami forecasting, tsunami hazard & risk assessment
- Weather, Climate and Hydrological Research and Development
  - ▲Forecasting products include rain, MSLP, wind, and temperature (3-5 days lead time on a daily basis, with 9 × 9 km resolution)
  - ▲ River basin outlooks, flood forecasting, tidal surge forecast, hydrological modelling tools (MIKE 11, HEC series), drought early warning system
  - ▲Dynamic downscaling based on regional climate model (RegCM4)
- Capacity Building in End-to-End Early Warning

— ADB (Asian Development Bank)

• URL: http://www.adb.org/

• Description

ADB is taking an integrated approach to meeting the disaster risk management needs of developing member countries. Currently, there are 7 sector groups and 8 thematic groups in ADB. Environment, Climate Change, and Disaster Risk Management is one of the 8 thematic groups in ADB, and its focus areas are: i) Integrated Disaster Risk Management, ii) Post-disaster Response, Rehabilitation and Reconstruction, iii) Nepal 2015 Earthquake: ADB's Response, iv) Typhoon Haiyan: ADB's Response, and v) Asian Tsunami: Ten Years On.

The ADB's disaster risk reduction focuses on interventions to tackle hazards directly. This includes reducing the probabilities of landslides and flooding through forest conservation on steep slopes; reducing exposure to hazards by methods such as supporting the integration of disaster risk considerations into land use planning; and reducing vulnerability with efforts such as supporting livelihood diversification into more resilient occupations, rainwater harvesting, and community early warning systems.

Especially, ADB has established an Integrated Disaster Risk Management (IDRM) Fund supported by the Government of Canada as a research to assist the development of innovative regional disaster risk management solutions in Southeast Asia developing member countries, i.e. Cambodia, Indonesia, Laos, Myanmar, Philippines, Thailand, and Viet Nam.

The IDRM Fund will support projects that are: i) regional in nature and focuses on issues that require cross-border disaster risk management (DRM) efforts; ii) aligned with regional DRM priorities of Southeast Asia DMCs; iii) introduces innovative solutions; iv) promotes community-based, gender-focused, and socially inclusive interventions on DRM; and v) supports stronger engagement with civil society and the private sector.

— The WB (The World Bank)

• URL: http://www.worldbank.org/

• Description

The WB has emerged as the global leader in disaster risk management (DRM), supporting client countries to assess exposure to hazards and address disaster risks. The WB's DRM provides technical and financial support for risk assessments, risk reduction, preparedness, financial protection, and resilient recovery and reconstruction.

A global partnership managed by the World Bank and supported by 34 countries and 9 international institutions, acts as a financing and technical body that supports DRM across the World Bank Group. The WB has three thematic programs on DRM that are: i) the small island states program, ii) the disaster resilience analytics program, and iii) the hydromet program.

The World Bank Group (WBG) works closely with more than 400 external partners on disaster risk management (DRM), including globally leading universities, the insurance sector, the risk modeling industry, civil society organizations, foundations, technical and development agencies of national governments, as well as UN and other multilateral agencies.

— The UNISDR (The United Nations Office for Disaster Risk Reduction) Regional Office for Asia-Pacific

• URL: https://www.unisdr.org/asiapacific

• Description

The United Nations Office for Disaster Risk Reduction (UNISDR) is established in December 1999 by the UN General Assembly to serve as the focal point in the United Nations system for the coordination of disaster reduction and to ensure synergies among the disaster reduction activities of the United Nations system and regional organizations and activities in socio-economic and humanitarian fields.

The UNISDR supports the implementation, follow-up and review of the Sendai Framework for Disaster Risk Reduction 2015-2030. The UNISDR is one of the UN system and they are closely cooperate with twenty-nine (29) specialized UN agencies and organizations with the respective expertise, networks and resources to reducing disaster risks.

The UNISDR Regional Office for Asia-Pacific is located in the Bangkok, Thailand, and the office covers 27 countries and 16 territories. It has sub-regional offices in Suva, Fiji for the Pacific and a liaison office in Kobe, Japan.

The Asia Pacific Regional Office supports on-going disaster risk reducing actions of people, governments, United Nations Country Teams, regional and international organizations, and the many stakeholders exposed to various hazards and risks.

— ASEAN Committee on Science and Technology (COST)

• URL: http://astnet.asean.org/

• Description

ASEAN Permanent Committee on Science and Technology was established in 1971 on a behalf of ASEAN Declaration of 8 August 1967 with the mandate of ASEAN cooperation in science and technology, which pursues collaboration between the ASEAN member states on matters of common interest in the economic, social, cultural, technical, scientific, and administrative fields.

Its initiation was from Ad-hoc Committee on Science and Technology in Jakarta, 1970. ASEAN COST was designated by following the rationalization of the ASEAN operations in 1978.

The ASEAN COST adopted the objectives and terms of reference of the Permanent Committee at Baguio City, Philippines, on 20-22 June 1978. Since then, the ASEAN COST has driven the ASEAN S&T policy, management and implementation of programmes in accordance with mandates laid down by the Summits of ASEAN Heads of State and Government and by the Meetings of the ASEAN Ministers for Science and Technology.

The principal objectives for ASEAN cooperation in science and technology are:
to initiate and intensify regional cooperation in scientific and regional activities;
to generate and promote development of scientific and technological expertise and manpower in the ASEAN region;
to facilitate and accelerate the transfer of scientific developments and technologies among ASEAN countries and from the more advanced industrialized countries to the ASEAN region;
provide support and assistance in the application of the results of research and development, and in the more effective use of natural resources in the ASEAN region; and
to provide support towards the implementation of present and future ASEAN programmes.

The ASEAN COST is responsible for supporting the annual Meetings of the ASEAN Ministers for S&T, which sets the policies for the ASEAN S&T cooperation, by providing directions, coordinating activities of sub-groups, creating public awareness of regional S&T activities and their contribution to economic development, and reviewing overall progress of collaboration that includes the progress of its relations with the ASEAN's Dialogue Partners as well as other external collaborators.

The Chairmanship of the ASEAN COST is synchronized with the chairmanship of the Ministerial Meetings, i.e. in an alphabetical order of names of the ASEAN member states. The meetings of the ASEAN COST are hosted twice a year to review the progress of regional programmes, to provide support for new programmes and projects, and to give directions to the implementation of programmes and projects by its sub-groups. The leading official in the ASEAN COST is the national COST Chairman, and generally is of the highest rank in the administration in charge of science and technology.

The ASEAN COST is supported by the ASEAN secretariat. The S&T Division of the Sectoral Development Directorate of the ASEAN Economic Community (AEC) Department of the ASEAN Secretariat, provides the ASEAN COST with coordinating and technical support functions. The ASEAN COST reports to the Committee of Permanent Representatives to ASEAN and to the ASCC Council.

The ASEAN COST has nine sub-committees on biotechnology, food science and technology, infrastructure and resource development, meteorology and geophysics, microelectronics and information technology, marine science and technology, materials science and technology, sustainable energy research, and space technology and applications.

The sub-committee on meteorology and geophysics seem to be the most relevant to disaster risk management based on its primary goal of natural disaster mitigation.

— UNESCO (The United Nations Educational, Scientific and Cultural Organization)

• URL: http://www.unescobkk.org

• Description

UNESCO Bangkok provides strategic expertise, advisory, monitoring, and evaluation functions for making sustainable and profitable development, and covers all mandates of UNESCO: education, science, culture, communication, and information.

As Cluster Office, it is responsible for implementation of programmes in the "Mekong" contries – directly in Thailand, Myanmar, Lao PDR, and Singapore, and indirectly in support of UNESCO county offices in Hanoi and Phnom Penh.

A UNESCO Bangkok's programmes namely "Education for Sustainable Development (ESD)" and "Natural Science (NS)" deal with the issues of climate change and disasters, and science-based sustainable development.

ESD plays a role in climate change education that addresses actions and involvement required for climate change at local, regional, and global levels. It aims at promoting the effective integration of climate change education into educational programmes and school curricula.

Through ESD, publications have been published mainly for educating disaster risk reduction and cooperation for sustainable development from educators' viewpoints, e.g. "East Japan Earthquakes and Tsunami: Lessons for the Educational Sector", and "Reflections: Disaster Recovery from the Heart."

The NS portfolio was created in response to demands for regional cooperation and international attention to issues pertaining in Mekong countries across multiple disciplines of: Water Sciences – International Hydrological Programme (IHP); Ecological Sciences – Man and Biosphere Programme; Science Policy for Sustainable Development; UNESCO Engineering Initiative; cross-cutting issues such as climate change; as well as disaster risk reduction.

NS generally publishes scientific reports and guidelines for assessing natural resources, disaster risk reduction among others (e.g. status of groundwater, guide for earthquake- resistant construction).

— ICHARM (International Centre for Water Hazard and Risk Management under the auspices of UNESCO)

• URL: http://www.icharm.pwri.go.jp/index.html

• Description

In response to increasing water-related hazards in the world, many initiatives have commenced from UN and UNESCO, e.g. the International Decade for Natural Disaster Reduction (IDNDR), the international Strategy for Disaster Reduction (ISDR), and et cetera. In the same context, the Japanese government proposed to establish the international centre for dealing with water-related disasters under the auspices of UNESCO, and achieved approval of 191 Member States at the 33rd General Conference of UNESCO.

The mission of ICHARM is to play a role as the Global Centre for Water Hazard and Risk Management by observing and analyzing natural and social phenomena, developing methodologies and toolandslide, building capacities, creating knowledge networks, and disseminating lessons and information for improving governance and helping all stakeholders who need to manage risks of water related hazards at global, national, and community levels. The hazards include floods, droughts, landslides, debris flows, tsunamis, storm surges, water contamination, and snow and ice disasters.

The three pillars of ICHARM are Research, Information, and Training for reducing water-related hazards by sharing knowledge and information.

2016 ICHARM Work Plan regarding natural hazards were or will be: (a) Technology for constantly monitoring, storing and using disaster information; (b) Support system for early warning capable of providing accurate information in a shorter period of time; (c) Assessment and planning technology for appropriate water resources management with insufficient information; (d) Technology for assessing the impact on local communities of water related disasters in flood plains and for evaluating the effect of investments in disaster risk reduction, and; (e) Technology for the effective use of water related disaster risk information to reduce disaster damage.

— HPN (Humanitarian Practice Network)

• URL: http://odihpn.org/

• Description

HPN is a media network to provide an independent forum for policy-making on the humanitarian sector by sharing and disseminating information, analysis and experience, and learned lessons. It aims to enhance the performance of humanitarian actions via contributing to individual and institutional learning, and HPN's audience is composed of individuals and organizations in humanitarian action.

HPN is located in the Humanitarian Policy Group at the Overseas Development Institute (ODI) in London. It deals with Climate and Environment to support climate compatible development and poverty reduction through high quality research and analysis.

Recent publications of ODI in relation to disaster risk reduction are "Strengthening disaster risk management in India: a review of five stat disaster management plans", "Resilience Scan: January-March 2016), and so forth.

ODI appears to be an institute to disseminate a wide range of research-based articles and reports for policy development.

— ERIA (Economic Research Institute for ASEAN and East Asia)

• URL: http://www.eria.org/

• Description

The Economic Research Institute for ASEAN and East Asia (ERIA) is an international organization established in 2007 among 16 heads of government, closely working with the ASEAN Secretariat, researchers and research institutes from East Asia to provide intellectual and analytical research and policy recommendations (e.g. policy research, dissemination of policy research, policy recommendation).

ERIA conducts research under the following three mail subjects: 1) Deepening Economic Integration, 2) Narrowing Development Gaps, and 3) Achieving Sustainable Development. Research covers a wide range of policy areas, such as trade and investment, globalization, Small and Medium Enterprises (SME) promotion, human resource and infrastructure development, and energy and the environment.

ERIA has conducted a series of research projects to aid the formulation of the Comprehensive Asia Development Plan (CADP). In addition, a research about Public Private Partnership (PPP) in ASEAN was conducted and produced a set of individual country profiles that summarize PPP policy, regulatory and institutional frameworks, and recent developments in each member country.

ERIA supports interdisciplinary efforts to develop new strategies for sustainable development in the region. This includes devising new growth strategies that move away from export-oriented development, and toward green development. ERIA conducts studies on sustainable social safety nets and disaster risk management in order to attain sustainability and resiliency in the region. The ERIA Energy Unit functions as a core entity that undertakes analytical works to enhance energy sustainability and efficiency in East Asia.

— UNDP (The United Nations Development Programme) in Asia and the Pacific

- URL: http://www.asia-pacific.undp.org/content/rbap/en/home/

- Description

UNDP's Regional Bureau for Asia and the Pacific (RBAP) concentrates its efforts on building the region's capacity to promote inclusive, pro-poor growth, effective governance, and sustainable and resilient development. We help our partners in identifying relevant solutions to today's complex, trans-boundary development challenges. We support them to design and implement large scale development initiatives that deliver lasting social, economic and environmental improvements in countries across the region.

UNDP in Asia and the Pacific is interested in Climate and disaster resilience and Sustainable development. UNDP supports nations and their people in building resilience to shocks to help ensure that the development gains made are sustained. We contribute to putting risk reduction on the national agenda in countries and help to integrate community development, recovery, income generation, disaster preparedness and support to livelihoods into more coherent programmes. UNDP supports countries in the development of adaptation strategies and assists them to pilot specific adaptation measures and countries to attract and direct public and private investment towards low- carbon development.

With UNDP support, national disaster and loss databases are operational in Indonesia, Sri Lanka, Nepal, Iran, Orissa and Tamil Nadu states in India. Cambodia, Myanmar, Viet Nam and Lao PDR are establishing databases as a tool to monitor disaster risk and prepare disaster management plans, and as criteria for allocation of funds, based on levels of risks.

UNDP has established a few noteworthy regional partnerships in addressing the complex challenges of disaster preparedness, conflict prevention and sustainable recovery: with the Association of Southeast Asian Nations (ASEAN), by contributing to the Declaration between the UN and ASEAN which calls for improved cooperation in preparedness, response and recovery; with the Regional Integrated Multi Hazard Early Warning System in Asia and Africa (RIMES), through a regional initiative on management of climate variability to advance climate risk management; and with the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG- IOTWS) through development of Indian Ocean-wide tsunami warning system and supporting risk assessment processes in coastal communities.

— The Asia Foundation

• URL : http://asiafoundation.org/about/

• Description

The dramatic economic, political, and social changes taking place across Asia offer unprecedented opportunities and new challenges for the region. They also hold tremendous possibilities for the mission and work of The Asia Foundation, an institution that has played a crucial role in Asia's development over the past six decades. To ensure that we continue to create positive and transformative impact for individuals, communities, and the region, we conducted a comprehensive strategic planning process, consulting a diverse range of voices, including our 18 country offices and our local partners in Asia.

The Asia Foundation improves lives, expands opportunities, and helps societies flourish across a dynamic and developing Asia. We work with innovative leaders and communities to build effective institutions and advance pathbreaking reforms. Together with our partners, we are committed to Asia's continued development as a peaceful, just, and thriving region of the world.

— Southeast Asia Disaster Prevention Research Institute (SEADPRI)

• URL : www.ukm.my/seadpri/?page_id=171

• Description

Universiti Kebangsaan Malaysia's Southeast Asia Disaster Prevention Research Initiative (SEADPRI-UKM), has been operating since 1 June 2008. Under the administrative structure of the Institute for Environment and Development (LESTARI), SEADPRI-UKM conducts multidisciplinary disaster related research at various scales, to support knowledge-based decision making on climatic, geological and technological hazards as well as enhance human capital and capacity in Malaysia and the region.

• Expertise:

- Landslide Assessment
  - ▲Kundasang Large-Scale Landslide Complex, Sabah
  - ▲Landslide & Slope Failure in Bukit Antarabangsa
  - ▲Debris Flow in highland areas, Malaysia
  - ▲Mitigating measures of slope failures along highways and housing development
  - ▲Identification and characterization of elements of geo-hazard to strengthen legislative measures in Malaysia
  - ▲Mechanisms of Natural and Human-induced landslides
- Earthquake & Tsunami
  - ▲Policy and Planning responses for earthquake & tsunami hazards
  - ▲Earthquake and Tsunami Information Portal for ASM
- Climate Change Adaptation and DRR
  - ▲Climate Resilient Development – Linking Science to Governance
  - ▲Indicators for Climatic Hazards and National Security
- Environmental Chemical Risk Assessment
  - ▲Transportation and Management of Hazardous Chemical
  - ▲Creating Silicon Nanostructure Platform Integrated with Nano-Biosensors for Rapid Determination of Biohazards to Ensure Food Safety

— International Institute for Environment and Development (iiED)

• URL : http://www.iied.org/

• Description

IIED is a policy and action research organisation. We promote sustainable development to improve livelihoods and protect the environments on which these livelihoods are built. We specialise in linking local priorities to global challenges. IIED is based in London and works in Africa, Asia, Latin America, the Middle East and the Pacific, with some of the world's most vulnerable people. We work with them to strengthen their voice in the decision-making arenas that affect them — from village councils to international conventions.

Capabilities:

- Biodiversity
- Climate change
- Communication
- Dry-lands and Pastoralism
- Economics
- Energy
- Fisheries
- Food and agriculture
- Forests
- Gender
- Governance
- Green economy
- Land acquisitions and rights
- Law
- Natural resource management
- Participation
- Partners
- Policy and planning
- Poverty
- Sustainable markets
- Urban
- Water

Expertise

- Climate change: Collaborating with partners to address the challenges of climate change, leading the way on policy, adaptation and resilience
- Human settlements: Working to reduce poverty and improve health and housing in the urban centres of Latin America, Asia and Africa
- Natural Resources: Working with partners to build capacity and shape policy for the fair and sustainable use of natural resources
- Shaping Sustainable Markets: Driving our efforts to ensure that markets contribute to positive social, environmental, and economic outcomes

Disaster Management Research Roadmap for the ASEAN Region

ASEAN Science-Based
Disaster Management Platform (ASDMP) Project

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