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The Probabilistic Risk Assessment Imperative in Philippine Climate Change Adaptation-Disaster Risk Reduction (CCA-DRR) Efforts

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ABSTRACT

The Philippines is ranked first in the World Risk Index 2022 according to the Germany-based Bündnis Entwicklung Hilft and the Institute for International Law of Peace and Armed Conflict (IFHV). The country will likely remain at the top rank of the global risk index over the next few decades, mainly due to the Philippines being in the Pacific Typhoon Belt, where the adverse impacts of climate change are predicted to get worse. To solve this predicament, intensive preparations through development planning are needed, and Probabilistic Risk Assessment (PRA) is required to capture and anticipate future hazards bigger than the historical record. The probabilistic approach is recognized in the Philippine Development Plan 2017-2022 and 2023-2028, the 2019 National Climate Risk Management Framework Policy of the Climate Change Commission (CCC), and the United Nations Disaster Risk Reduction (UNDRR) document entitled, "Why Invest in Probabilistic Risk Assessment?" as necessary for effective climate change adaptation actions. However, the Philippines has yet to realize the nationwide-scale implementation of PRAs in our CCA-DRR efforts, despite it being a strategy recommended by the national government to effectively address worsening natural hazard impacts that severely hamper national development. This paper highlights the importance of PRA in the context of Philippine Climate Change Adaptation and Disaster Risk Reduction (CCA-DRR) efforts to lower the cost of damage from floods, rainfall-triggered landslides, and storm surges and help communities attain their sustainable development goals. We recommend that these policies be systematically implemented without any more delay.

Keywords: Probabilistic Risk Assessment, Deterministic Risk Assessment, Climate Change, Climate Change Adaptation, Disaster Risk Reduction, Disasters, Haiyan Storm Surges

Abbreviations: CCC, Climate Change Commission; CCA-DRR, Climate Change Adaptation and Disaster Risk Reduction; CDP, Comprehensive Development Plans; CDRA, climate and disaster risk assessment; CLUP, Comprehensive Land Use Plans; CRE, Climate Risk Evaluation; CSCAND, Collective Strengthening of Community Awareness on Natural Disasters; DRR, Disaster Risk Reduction; DRMM, Disaster Risk Reduction Management; GHG, greenhouse gas; GDP, Gross Domestic Product; GPR, Ground Penetrating Radar; IFHV, Institute for International Law of Peace and Armed Conflict; IPCC, Intergovernmental Panel on Climate Change; MGB, Mines and Geosciences Bureau; NCRMF, National Climate Risk Management Framework; NDRA, national disaster risk assessment; NEDA, National Economic Development Authority; NGAs, National Government Agencies; UNDRR, United Nations Disaster Risk Reduction; PCRA, Probabilistic Climate Risk Assessment; PRA, Probabilistic Risk Assessment; RA, Republic Act; SDGs, Sustainable Development Goals; SIAD, Sustainable Integrated Area Development, UNDP, United Nations Development Program; UP, University of the Philippines.

I. INTRODUCTION

Over the last decade, there has been significant progress in the country's disaster risk reduction efforts as seen from the lowered average number of fatalities found in the International Disaster Database EM-DAT (Guha-Sapir et al. 2023). The average number of fatalities from hydrometeorological hazards went down significantly from 1,253 per year for the period 1986-2013 to 284 per year from 2014-2022 (Figure 1A). However, in terms of the cost of damages, the average has remained the same during the same two periods with about 50 billion pesos lost each year from hydrometeorological hazards (Figure 1B). This predicament is of grave concern as damages and losses from disasters eat up 0.5% of the Philippine annual GDP (Department of Finance 2021). It affects economic progress and hinders efforts to alleviate poverty and attain most of the sustainable goals. With climate change predicted to intensify cyclones with more powerful winds, higher and more frequent storm surges, delivery of more rains that trigger bigger floods, and increased landslide occurrence, our predicament with disasters will get worse highlighting the need for a robust national strategic plan that needs to address this lingering and growing problem.

Here, we highlight the probabilistic risk assessment (PRA) approach contained in the 2017-2022 and 2023-2028 Philippine Development Plan, the 2019 National Climate Risk Management Framework Policy of the Climate Change Commission (CCC), and the United Nations Disaster Risk Reduction (UNDRR) document on Why Invest in Probabilistic Risk Assessment (UNISDR 2017). Probabilistic risk is the chance of something adverse occurring and its assessment evaluates the likelihood of such an event. It contains the idea of uncertainty because it incorporates the concept of randomness. In the context of disaster risk, probability refers to the frequency of occurrence or the return period of losses associated with hazardous events (UNISDR 2017a). Assessing risk probabilistically remains

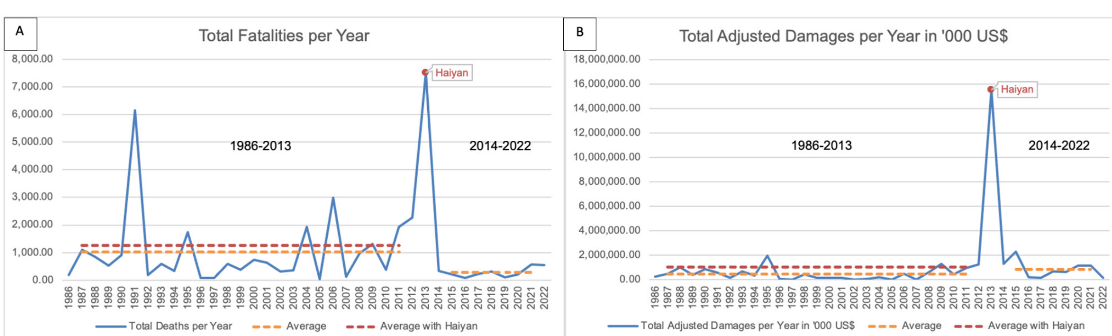

Figure 1. A) Total Fatalities vs year from 1986-2022 with a significant lowering of fatalities per year from 2014-2022. B) Total damages to property from hydrometeorological hazards per year adjusted to the current value in US$. No significant lowering of damages is evident from 1986-2022. Data source: CRED/OFDA International Disaster Database (Guha-Sapir 2023); accessed February 2, 2023. Note: Fatality and damage database incomplete for the year 2022.

a challenge, particularly because of the number of factors to account for and because the risk is not static and is increasingly influenced by a number of other drivers, including climate change. However, probabilistic risk assessments are increasingly becoming the standard for disaster risk assessment because they are more comprehensive than the deterministic approach which only considers the impact of a single risk scenario (UNISDR 2017c).

We also highlight the existing policies of the government that serve as bases for the implementation of PRA for development planning of all cities and municipalities of the country. Lastly, we provide examples of past Philippine disasters to illustrate the use and importance of the PRA approach in comprehensive land use, disaster prevention and mitigation, and local climate change action plans. For most people and even decision-makers, the term probabilistic risk assessment is difficult to comprehend particularly on how it applies to the development efforts of the country. Analyzing international and local policy and legal provisions as well as providing examples in this study would hopefully address this gap in the understanding by many of the meaning of probabilistic risk assessment in the context of attaining much desired sustainable development goals. The intent is to explain to government authorities and the Filipino people the importance of probabilistic risk assessment, with the goal to improve the CCA-DRR efforts of our country, actions that are directly linked with development.

As disasters are manifestations of unresolved problems of development (Hagman 1984), a key approach to solve the threat of future disasters is to plan communities to manage risk, reducing the consequences or probability of unfavorable events (Bender 1991). This includes incorporating scenarios that are bigger than what we have experienced and planning against the predicted impacts of climate change which many call “Climate Change Adaptation-Disaster Risk Reduction (CCA-DRR).” The term CCA-DRR is used instead of the traditional Disaster Risk Reduction (DRR) wording because it refers to planning and preparations against climate hazards which are natural hazards that will become more powerful and more frequent (IPCC 2022). These include hydrometeorological hazards such as floods, landslides, and storm surges that impact communities now and worse in the future because of climate change.

II. BACKGROUND ON CLIMATE CHANGE

Over the last century, civilizations have altered the atmosphere through industrialization and deforestation so as to cause our climate to change in an unprecedented manner. The rapid changes in climate consequently have brought us to experience harsh natural phenomena that threaten populations all over the globe. Climate change consequences, which manifest in records as increased rainfall, higher temperature, more intense cyclones, and rising sea-level, impair development and heighten the vulnerability of communities to natural hazards.

The consensus amongst reputable climate scientists worldwide points to a rapidly changing climate, which needs to be addressed accordingly and in a timely fashion. The majority agree that there is a need to stem or slow down the current progression of climate change through the immediate and concerted global effort to reduce greenhouse gas (GHG) emissions and increased carbon sinks. Clean and renewable energy and reforestation are among the suggested solutions (Kelman, 2015). Clearly, the international community recognizes the growing threat of climate change and calls for immediate adaptive measures to counter its ill effects to promote the resilience of ecosystems and societies. Such adaptive measures must go beyond mere technological options that are mainly focused on building infrastructure and other similar measures (Perez et al. 2010).

Resilience against climate change requires effort and resolve by all sectors of society. Resilience builds the ability of a community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNDRR 2017d). To become resilient against the adverse impacts of climate change, action plans are needed for adaptation, which refers to adjustments of natural or human systems in response to actual or expected stimuli, or their effects to moderate the harm or exploit beneficial opportunities (IPCC 2007). In the Philippines, local government units (LGUs) are required to incorporate adaptation plans in the formulation of Comprehensive Land Use Plans (CLUP) and Comprehensive Development Plans (CDP) (Republic Act 7160 1991). Since climate change-enhanced natural hazards can lead to disasters, it is vital that all institutions down to the family level include in their efforts to build resilience, fused CCA-DRR plans.

Impacts of Climate Change

Increased levels of GHG in the atmosphere will cause several effects. Among them are increased air temperatures, sea-level rise, acidification of oceans, severe droughts, and more powerful typhoons. These effects are measurable and can be compared with the historical record of our climate. Some of the measured effects are even worse than the projected changes reported by the Intergovernmental Panel on Climate Change (IPCC 2022).

A significant effect of global warming is the melting of polar ice, which in combination with the thermal expansion of water causes the sea level to rise. After at least 2,000 years of little change, the sea level rose by roughly 20 cm over the past century (Bindoff et al. 2007). For the period 1992-2011, the global sea level was observed to increase at a rate of about 3 millimeters per year. This rate is the global average and can be thought of as resulting from all the locations measured on the surface of the ocean. If we limit the region to the area around the Philippines, the rate for the same period is about 6 millimeters per year (Clavano 2012). Assuming that the rate of change of sea level around the Philippines for the period 1992-2011 does not change, we can expect waters to rise further by at least 20 cm in the next 40 years.

Seawater has also become significantly more acidic since 1750 and is expected to continue becoming more acidified due to an increase in carbon dioxide concentration. According to marine scientists, ocean acidification will take centuries to reverse. Ocean acidification affects calcification, a natural mechanism used by sea creatures to build their shells and skeletons. A decrease in the ability of corals, mollusks, and planktons to generate their biogenic carbonate hard parts will have widespread negative effects on coral reefs and marine productivity. A 3◦C increase in ocean temperatures constitutes a real threat to Philippine coastal environments with ocean acidification as a possible cause of the poor condition of coral reefs, with only 5% remaining in excellent condition (McGlone 2015).

Droughts have been happening in the Philippines with the earliest record in 1644 (Blaire and Robertson 1906). In the 1900s, extremely dry conditions affected the Philippines in 1903, 1912, 1938, 1969, 1973, 1978, 1983, 1990, 1992, and 1998 (de Guzman 2011, Warren 2013). In 2016, a dry spell followed an El Niño event, a natural phenomenon associated with warm ocean water in the central and east-central equatorial Pacific and the coast of South America that normally triggers droughts in the Philippines. Previous to the 2016 Philippine drought, sea surface temperature related to an El Niño year was the highest in recorded history in the Pacific. Drought conditions in the Philippines have become more prevalent since the mid-70s and are expected to become more severe in upcoming years due to our changing climate.

Because of the direct influence of ocean water properties on atmosphere circulation, warming seas have intensified by 12-15%. Potentially catastrophic category 4 and 5 storms that make landfall have doubled to tripled in number whereas the character of storms that remain in open water did not significantly change. Projections on ocean surface warming as a direct effect of increased atmospheric GHG concentration suggest a further intensification of typhoons, which means a bigger threat to vulnerable communities in the West Pacific region, including the Philippines (Mei and Xie 2016).

The impacts of climate change will not be experienced in isolation but will affect humans in the context of the way we live: water shortages for local consumption and agricultural use will affect billions of people. The risk to natural hazards such as floods, landslides, and storm surges brought by extreme storms will escalate and undermine global efforts to alleviate poverty. Forest fires will become more prevalent, devastating, and more difficult to manage. Rising sea levels will threaten coastal communities where there are dense populations and high-value agricultural lands. Access to affordable food, sufficient to maintain a proper diet, will be limited and threaten food security (United Kingdom Met Office 2015). These effects are imminent and prompt actions to combat these threats through proper planning by communities that are adaptive and resilient to climate change.

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III. METHODS

A literature review was conducted to assess the legal basis to promote in the Philippines the UNDRR action guidelines for National Risk Assessment (UNISDR 2017b) on "Why Invest in Probabilistic Risk Assessment (UNISDR 2017a). Current policies and practices on deterministic (single-scenario) and probabilistic risk assessment (multi-scenario) approaches were compared and assessed in the study.

Attention was given to 3 disasters over the last 11 years that led to mass casualties. These are Pablo (2012), Haiyan (2013), and Naga City, Cebu Disasters (2019). Counterfactual evidence is presented in each of the examples provided to assess if an alternative method such as the PRA approach could have averted the disaster in terms of casualties or been useful for post-disaster resettlement. Other more recent disasters were also mentioned with emphasis on the latest disaster that transpired in Mindanao when Typhoon Paeng was in the Philippine Area of Responsibility (PAR).

The comparison of the PRA and deterministic risk assessment is then discussed. Emphasis is made on the methods used for each of the two types of approaches and their relevance to Philippine Disaster Risk Reduction and Climate Change Adaptation efforts. Recommendations based on the comparative analysis are provided as a way forward to attain the Sustainable Development Goals (SDGs) of all 1634 cities and municipalities of the country (PSA 2020)

IV. RESULTS AND DISCUSSION

A. International and National Policies and Guidelines

Table 1 lists the international and national policy guidelines on the use of probabilistic risk assessment from 2016 to 2023.

UNDRR Guidelines

The United Nations Office for Disaster Risk Reduction in 2016 developed guidelines on national disaster risk assessment (NDRA). It is part of a series to support the Sendai Framework for Disaster Risk Reduction 2015-2030. Over 100 leading experts from national authorities, international organizations, non-governmental organizations, academia, think tanks and private-sector entities collaborated to formulate the thematic guidelines dubbed "Words into Action." The results focused on the Sendai Framework's first Priority for Action: Understanding Disaster Risk, which is the basis for all measures on disaster risk reduction and is closely linked to the other three Priorities for Action (UNISDR 2017b).

The intent of creating the guidelines for NDRA was to motivate and guide countries in establishing a national system to understand disaster risk to act as the central repository of all publicly available risk information systems. It was made also to encourage NDRA leaders and implementing entities to aim for holistic assessments that provide an understanding

Table 1. Summary of policy guidelines on the use of probabilistic risk assessment.

Policy Guideline	Type	Year	Source Agency/Institution
Guidelines on National Disaster Risk Assessment	International	2016	United Nations Disaster Risk Reduction Office
PDP 2017-2022	National	2017	NEDA
CCC-2019-001	National	2019	Climate Change Commission
CCC-2021-003	National	2021	Climate Change Commission
CCC-2021-006	National	2021	Climate Change Commission
CCC-2021-007	National	2021	Climate Change Commission
PDP- 2023-2028	National	2023	NEDA

of the different dimensions of disaster risk (hazards, exposures, vulnerabilities, and capacities). The said guidelines also provide information on the drivers of risk – such as climate change, poverty, inequality, weak governance, and unchecked urban expansion. The series is composed of three parts, namely: The main body, which provides policy guidance on what it takes to conduct and successful disaster risk assessment; Special topics consisting of modules on specific issues that need to be considered in the design and construction of national disaster risk assessments; and hazards specific risk assessment, comprised of modules that provide in-depth information on the conduct of risk assessment for specific hazards (UNISDR 2017b).

Under special topics, there is a document, entitled, "Why Invest in Probabilistic Risk Assessment", which is of particular interest to Filipinos as it applies to the manner by which we should conduct risk assessments in our country for effective disaster risk reduction and climate change adaptation. This is because policy and investment decisions for managing disaster risk rely on a sound knowledge of the risks. "Over the past decade, there was substantial progress made globally to improve tools for hazard and risk assessment. This progress was in the form of probabilistic models which originated from the insurance sectors. Over time, probabilistic models have become a standard tool to facilitate better risk management in the insurance and reinsurance industries and then later for risk management strategies in civil society, government, and the private sector enabling risk reduction, risk adaptation and risk transfer mechanisms to be assessed individually with a holistic approach (UNISDR 2017a)."

"Probabilistic risk modeling estimates risk in terms of people affected, loss, and damages and at the same time provides uncertainties for those estimates. The probabilistic approach differs from the deterministic risk assessment approach, which considers the impact of only a single risk scenario which is the worst-case scenario based on the historical record (UNISDR 2017a)." In the Philippines, flood, rainfall-triggered landslides, and storm surge maps are based on the historical record. Flood and landslide susceptibility maps are based on the methodologies used by the Mines and Geosciences Bureau (MGB) and prepared under the Collective Strengthening of Community Awareness on Natural Disasters (CSCAND) program (UNDP n.d.). The MGB methods (Manzano 2014), include: 1) Interpretation and analysis of remote sensing data (aerial photographs and satellite images) and other thematic maps such as geologic maps, drainage maps, slope maps, and vegetation maps; 2) Ground Truth; 3) Geomorphological and geological assessment; 4) Ground Penetrating Radar (GPR); and 5) Anecdotal Accounts. Storm surge hazard maps prepared under the same program prior to Haiyan are also deterministic and rely mainly on historical accounts and records. "PRA, on the other hand, considers all possible scenarios, their likelihood, and associated impacts, including those induced by climate change. The PRA approach communicates risk based on the likelihood of an event with its associated severe impacts (UNISDR 2017b)."

PDP 2017-2022 and 2023-2028

In chapter 20, page 319 of the PDP 2017-2022 on Ensuring Ecological Integrity, Clean and Healthy Environment, the National Economic Development Authority (NEDA) identified in their assessment the "lack of capacity to use the available geospatial information, unavailability of appropriately-scaled probabilistic multi-hazard maps and coarse spatial resolution of available maps "(NEDA 2017) as some of the challenges in Philippine efforts on CCA DRR. To address these challenges, NEDA outlined strategies, which they aptly called "Sustainable Integrated Area Development (SIAD) and participatory environmental governance as an overarching principle in implementing the various strategies to achieve the outcomes. SIAD will be adopted to address ecological, economic, political, cultural, societal, human, and spiritual challenges and opportunities in a specific area. It will be implemented in an integrated manner to ensure social justice and in order to improve the quality of life of the people (NEDA 2017)."

In Subsector Outcome 3 on Adaptive capacities and resilience of ecosystems, NEDA outlined "strategies to develop, maintain, and ensure the accessibility of climate and geospatial information and services. This includes the following activities: (a) completing the coverage and ensuring access to large-scale (1:10,000) probabilistic hazard maps; (b) conducting a nationwide geo-referenced mapping of exposed elements; (c) developing risk estimation models to determine the value of potential loss and damage for different scenarios; (d) improving the loss and damage database to generate disaggregated information about vulnerable and affected groups; (e) identifying and mapping natural ecosystems that contribute to resilience; and (f) standardizing definition and methodologies to measure DRRM and CC variables." The first item included in these strategies for geospatial information services is ensuring access to probabilistic hazard maps.

The PDP 2023-2028 also recommends the PRA approach as a strategy to achieve climate and disaster resilience (NEDA 2023). In the PDP 2023-2028 document, several enabling policies and plans have been adopted to ramp up climate action and disaster resilience, which include the strengthened implementation of the National Climate Risk Management Framework or NCRMF (CCC 2019-001). The NCRMF, which is a Climate Change Commission policy, stipulates the use of the Probabilistic Climate Risk Assessment (PCRA) to determine the risk ranking of communities for Climate Risk Evaluation (CRE). The PCRA shall generate the needed localized baseline information on climate risk faced by vulnerable communities and their support systems for potential climate-related hazards (CCC 2019).

Climate Change Commission Policies

The Climate Change Commission also issued policies regarding PRA. This is contained in the CCC resolution no. 2019-001, entitled, "Resolution Adopting a National Climate Risk Management Framework (NCRMF) to Address the Intensifying Adverse Impacts of Climate Change. Specifically, the NCRMF promotes multi-sectoral and multi-stakeholder activities of the National Government Agencies (NGAs) and LGUs through PCRA and Climate Risk Evaluation (CRE)." PCRA is defined in the document to consider all possible futures, likelihoods, inherent uncertainties, and associated impacts of climate change. The PCRA shall generate the needed localized baseline information on climate risk faced by vulnerable communities and their support systems for potential climate-related hazards. CRE, on the other hand, involves the determination of risk ranking based on PCRA results. Standard methodologies for quantitative risk ranking, i.e., low, medium, and high, shall be applied as a systemic basis for climate risk management (CCC 2019)."

Climate Change Resolution no. 2019-001 was unanimously adopted by Commissioners Emmanuel de Guzman, Engineer Noel Antonio V. Gaerlan, and Attorney Rachel Anne S. Herrera, during the Special Commission Meeting on 25 January 2019 at the Chairperson's Room, Climate Change Commission, 6th floor, First Residences, J.P. Laurel Street, San Miguel, Manila. The said resolution was transmitted to and received by the Office of the President on 8 February 2019 and passed into effectivity on March 11, 2019, per section 6 of RA 9729, as amended, as no veto was issued by the CCC Chairperson, President Rodrigo Roa Duterte.

Succeeding Resolutions, such as the Commission's Results Framework and Organizational Structure policies are likewise anchored on the NCRMF. These Commission Resolutions have reference to probabilistic risk assessment. They have been duly approved by the CCC and became effective thereafter.

- CCC resolution no. 2021-03 and annexes – Resolution adopting the results framework of the Climate Change Commission to increase its responsiveness in fulfilling its mandates under Republic Act (RA) No. 9729, as amended, and other existing laws
- CCC resolution no. 2021-06 – Resolution adopting the plans and targets relative to the results framework of the Climate Change Commission
- CCC resolution no. 2021-07 – Resolution adopting the proposed organizational structure of the Climate Change Commission

B. The Present Situation: What We Need to Prepare For

Despite the legal policy provisions on PRA defined in the PDP 2017-2022, PDP 2023-2028, and CCC resolutions 2019-001, 2021-03, 2021-06, and 2021-07, there is still unavailability of appropriately scaled probabilistic multi-hazard maps for flood and other fast-onset hydro-meteorological hazards on a nationwide scale. This is unfortunate for the country because in the absence of PRA and with the continued use of worst-case, single-scenario susceptibility (hazard) maps, created based on anecdotal accounts and experts' opinions, we fail to anticipate bigger events than the historical record. These include projected adverse impacts of climate change, which are larger than what we have experienced. Cyclones will become stronger, will deliver more rainfall, and carry more powerful winds. Rainfall, which is not a hazard per se because nobody dies from it, will spawn bigger floods, and trigger more landslides thereby threatening more communities (IPCC 2022). Winds with unprecedented velocities will damage more infrastructure (e.g., transmission lines, towers, rooftops) and, also generate higher-level and extremely devastating storm surges.

Floods, landslides, impactful winds, and storm surges are the fast-onset hydrometeorological hazards that communities need to prepare for, and they need to reflect scenarios beyond the historical record. This is imperative if we are to anticipate the projected adverse impacts of climate change. Including PRA for these hazards allows the community to generate anticipatory plans across various sectors of society such as energy, infrastructure, environment, health, tourism, and education. This is real and truthful Climate Change Adaptation which refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. In simple terms, countries and communities need to develop adaptation solutions and implement actions to respond to the impacts of climate change (e.g., flood, rainfall-triggered landslide, and storm surges) that are already happening, as well as prepare for future impacts (UNFCC 2022).

C. Hard Lessons: Averting Disasters

Disasters transpire in various ways, and we learn from the hard lessons once they unfold. Three examples are presented to show how PRA could have minimized or averted these disasters. These are the 2012 Pablo Floods and Debris Flows, the 2013 Haiyan Storm Surge, and the 2018 Naga Landslide Disasters. The same identified mistakes from these disasters should not be repeated as they are extremely costly in terms of loss of lives and damage to property

Pablo Floods and Debris Flow

Category 5 Super Typhoon Bopha, the world's worst storm of 2012, formed abnormally close to the Equator, and its landfall on Mindanao set the record proximity to the Equator for its category. Its torrential rains generated an enormous debris flow in the Mayo River watershed that swept away much of the village Andap in the New Bataan municipality, Compostela Valley, burying areas under rubble as thick as 9 m and killing 566 people. Established in 1968, New Bataan had never experienced super typhoons and debris flows. This unfamiliarity compounded the death and damage (Rodolfo et al., 2016).

Before Super typhoon Pablo's landfall in December 2012, Davao del Sur, residents of New Bataan were forcibly evacuated to Barangay Andap about 3.5 km from the center of the town. This evacuation center can be identified in the Mines and Geoscience Bureau (MGB) hazard map to be an area of low susceptibility to landslides (Figure 2A). It is in fact, the worst site for an evacuation center because it is located at the mouth of a mountain drainage network and at the apex of an alluvial fan - the most dangerous place in the area for floods and debris flows (Figure 2B). The downloadable hazard map of the MGB for New Bataan (MGB n.d.) was changed within weeks after the Pablo disaster in New Bataan from a low-landslide susceptible area into a high-flood susceptible area. In both maps, however, the hazard assessment incorrectly depicted the susceptibility to hazards of the evacuation area because debris flows are a type of landslide. The evacuees perhaps also willingly agreed to be placed in the shelter at Barangay Andap because they themselves have not experienced floods of the same magnitude as those delivered by Typhoon Pablo. This can be due to the fact that Mindanao is not as affected by severe weather events relative to places in Luzon and Visayas which are battered by about 7-10 tropical cyclones per year on average (Takagi and Esteban 2013). In the aftermath, the few survivors of the deluge echoed the famous phrase that all disaster survivors always narrate, "they have not seen this type of flood before and the deluge was unexpected". This is what happens when we keep on using the deterministic approach which is mainly based on anecdotal accounts and subjective expert opinions. As demonstrated in this study, the deterministic approach to assess hydrometeorological hazards in the Philippines does not reflect multiple scenarios of hazards that include bigger events than the historical record as well as hazardous events predicted by scientists to occur because of climate change.

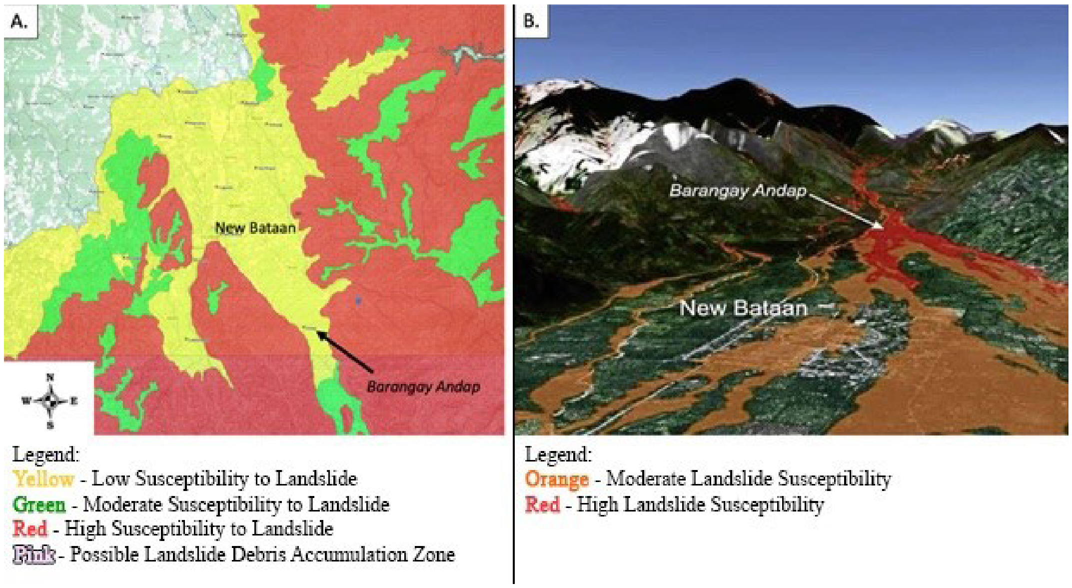

Figure 2. A) Landslide susceptibility map of Manat, Sabaki, and Sumlog River Quadrangle, Compostela Province, Philippines prepared by the MGB before the Pablo debris flow disaster (MGB n.d.). The arrow points at Barangay Andap where the evacuation center was placed B) Debris flow map of New Bataan, Compostela Valley (Rodolfo, et.al 2016).

Haiyan Storm Surges

On 8 November 2013, Typhoon Haiyan, local name Yolanda, made landfall in the central Philippine islands region. Considered one of the most powerful typhoons ever to make landfall in recorded history, the 600 km diameter Typhoon Haiyan crossed the Philippine archipelago, bringing widespread devastation in its path. Strong winds, heavy rainfall, and storm surges caused extreme loss of lives and widespread damage to property. Storm surges were primarily responsible for the 6300 dead, 1062 missing and 28,688 injured in Haiyan's aftermath (NDRRMC 2013). The devastating Haiyan storm surges are one of the biggest in living memory, which exacted a high death toll despite its early prediction. There were many lessons learned from this calamity that can serve as a useful reference to mitigate the heavy impact of future storm surge events in the Philippines and elsewhere (Lagmay and Kerle 2015, Lagmay et al 2015).

The tragedy during the onslaught of Haiyan Storm Surges is attributed to many factors. One that is striking is the underestimation of the extent of storm surge inundation by the deterministic, single-scenario storm surge hazards maps (Figure 3A). These hazard maps with a published date of 2010 were prepared by the national government CSCAND agencies under the Hazards Mapping and Assessment for Effective Community-Based Disaster Risk Management (READY) Project (UNDP n.d.) for Leyte and Samar. Examination of the location of evacuation centers revealed that all designated evacuation centers were placed outside of the CSCAND-identified storm surge hazard areas. Seventy percent of these designated evacuation centers were inundated by the storm surges of Haiyan where many people died. Those people followed the command of the LGU and also thought they were good shelters from the storm as they did not realize the gravity of the storm surges. Victims had no experience with such an event where inundation reached as much as 2-3 km inland.

After Haiyan, probabilistic (multi-scenario) storm surge hazard maps were created for Tacloban City and many places in the Haiyan-affected areas of the Central Philippines region (Joint Memorandum Circular, 2014). Different storm surge scenarios depicted varying inland inundation (Figure 3B). The largest scenario is comparable with that of Haiyan and is regarded to be the most reliable according to the report by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ 2015). The largest storm surge scenario, which GIZ assigned with a 90-year

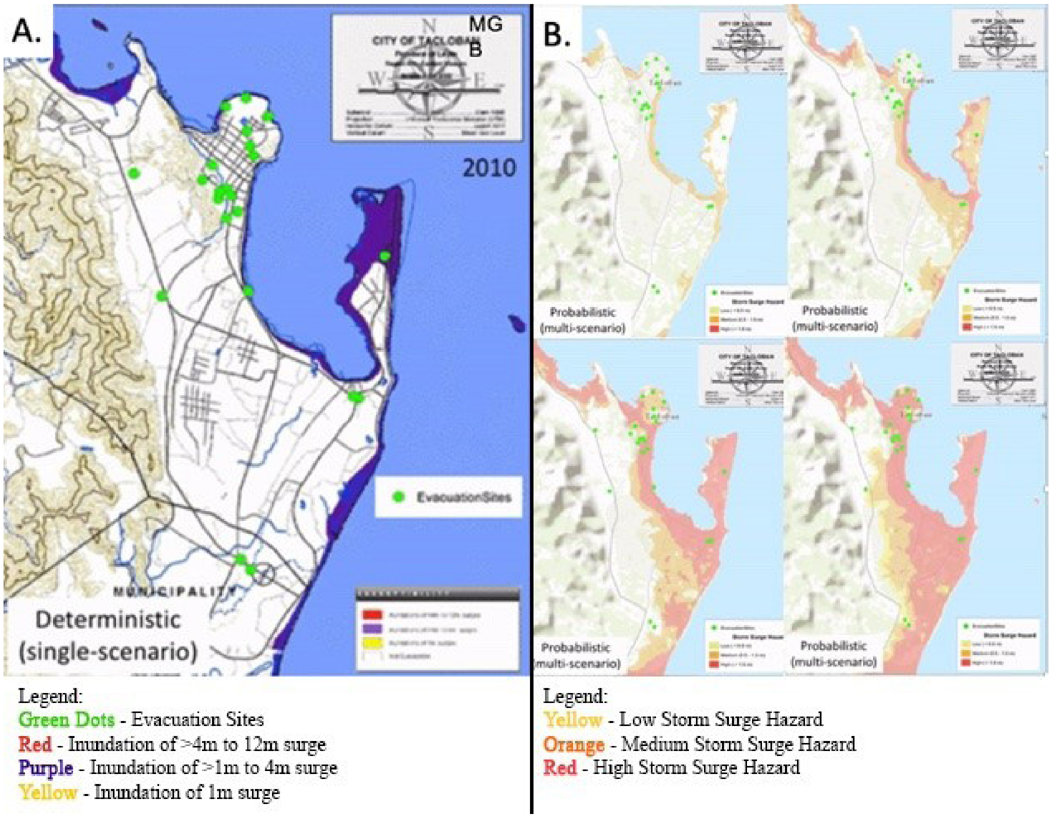

Figure 3. A) Deterministic (single scenario storm surge hazard map) based on anecdotal/historical accounts and expert opinion provided by CSCAND under the READY Project (UNDP, n.d.) B) Probabilistic (multi-scenario) storm surge hazards maps for Tacloban City. The green dots in all of the maps are the locations of the evacuation centers (DOST-Project NOAH 2016).

return period, showed that almost all of the evacuation centers were in places exposed to storm surges. Many people died in the evacuation centers during Haiyan which is a clear example of the danger of using hazard maps crafted based on anecdotal accounts, which are bereft of scenarios that are bigger than what people remember or what is in the historical record. After Haiyan, there were reports highlighting newspaper articles published in 1897 that told of massive inundation in Tacloban (Lotilla, R. 2013; Soria et. al. 2016). However, the CSCAND maps did not reflect them in the maps that were distributed to the LGUs of Leyte in 2010. Had there been probabilistic storm surge hazard maps that correctly depicted the inundation extent before Haiyan made landfall, response actions could have been very much different with significantly less costly results, especially in terms of the death toll.

Naga Landslide

On 20 September 2018, a massive landslide devastated Naga City, Cebu. The Naga City Landslide claimed the lives of 78 villagers and injured 18 while six people remained missing and are presumed dead. The majority of the fatalities were recovered at the landslide toe about 1.2 km from the 200-meter-high head scarp. This was due to the unexpectedly large landslide volume and unusually long runout, which surprised villagers at the landslide toe. Despite early warnings from developing fractures near the head scarp a month prior to the disaster, no action was taken by villagers at the landslide toe in Sitio Sindulan, Barangay Tinaan, and those in an adjacent area at the base of a cliff in Barangay Naalad (Figure 4). Only residents in Sitio Tagaytay, situated near the head scarp of the landslide, were evacuated by authorities the night before the mountain collapsed (Lagmay et al. 2020).

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The year before the fatal Naga landslide, the DRRM Plan of Naga City was completed, and duly approved by the Office of Civil Defense and Mandated Agencies (Figure 5A). Agency landslide hazard maps of Sitio Sindulan and part of Barangay Naalad, places in Naga City with the most number of deaths, were identified as areas with low landslide susceptibility, the lowest rating available in the map (Figure 5B). All other places on the same map are for flood susceptibility. Perhaps this was the reason why on the night prior to the Naga Landslide, only the residents of the Sitio Tagaytay at the head scarp of the landslide were evacuated. Those at the foot of the landslide were not evacuated as the DRRM plan did not identify the threat in the area. Many died in these

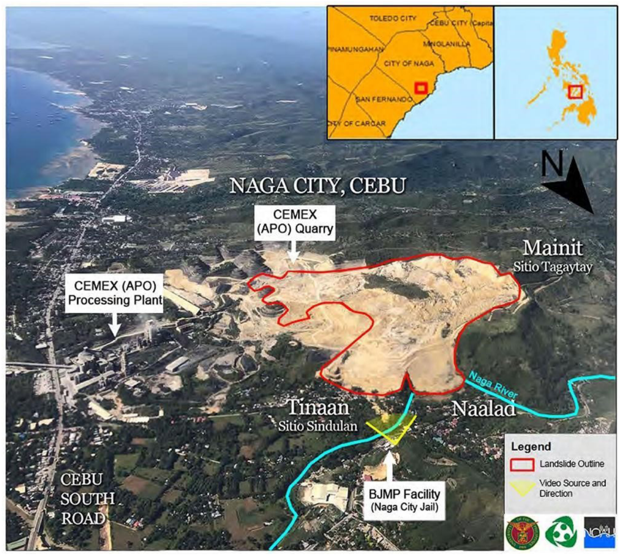

Figure 4. Aerial image of the Naga landslide taken a month after the incident. Numerous houses in Sitio Sindulan, Barangay Tinaan, and the village situated near the base of the cliff in Barangay Naalad were buried by the landslide debris (Lagmay et al. 2020).

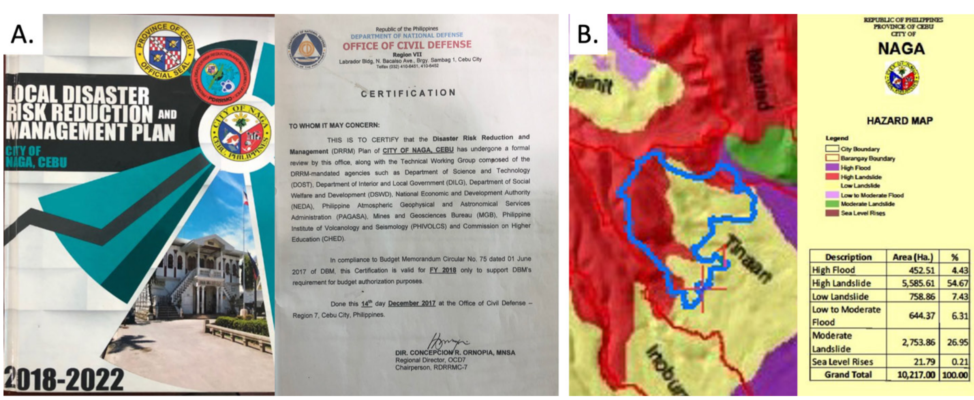

Figure 5. A) Local disaster risk reduction management plan of Naga City, Cebu for 2018-2022 (City of Naga, Cebu 2017) with certification from the Office of Civil Defense (OCD 2017) based on their review with the Technical Work Group composed of DRRM mandated scientific agencies (DOST, PAGASA, MGB, and PHIVOLCS). B) Landslide footprint of the Naga disaster overlain on the hazard map of Barangays Tinaan, Naalad, and Tagaytay with corresponding descriptions of the level of hazards for landslides (City of Naga, Cebu 2017).

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areas about 1.2 km downslope from the place where the landslide originated, buried by about 10 meters of rubble.

It is possible to have evacuated the residents of Sitio Sindulan, Barangay Tinaan, and parts of Barangay Naalad, had available NOAH landslide hazard maps of the area been used to complement the assessment process to evacuate due to the imminent landslide threat. The maps prepared by NOAH showed Sitio Sindulan, Barangay Tinaan, and parts of Barangay Naalad as places with moderate to high landslide hazards (Figure 6) because the methodology to assess the landslide threat included landslide runout on the top of the identification of mountain slopes that are unstable. Unfortunately, the NOAH landslide maps are not officially endorsed by the national government for use by LGUs despite the fact that these high-resolution hazard maps were made openly available as early as 2015 as part of a government-funded program and a major part of the Joint Memorandum Circular on the use of hazard maps for the Yolanda Corridor (Joint DENR-DILG-DND-DPWH-DOST Memorandum Circular No. 2014-01). Based on information gathered from LGUs, what is officially endorsed and promoted for use by LGUs on a nationwide scale to craft their respective community CLUP, LCCAP, CDRA, and DRMM Plans, are the deterministic susceptibility (hazard) maps created by the CSCAND agencies, which was started in 2004 (UNDP n.d.) and completed in 2011 for 1:50,000 scale maps (Gloria 2011) and 2014 for 1:10,000 scale maps (COA, 2016). According to Congressman Salceda (personal communication 2018), an official endorsement is necessary as LGUs are wary of using allegedly non-official NOAH maps due to Commission on Audit (COA) rules and regulations.

In the aftermath of the Naga Landslide disaster, problems arose in resettlement. Government authorities recommended the relocation of residents in highly susceptible areas to landslides based on the post-disaster geohazard assessment of MGB (Figure 7A). A total of 1,645 households in the "No Permanent Habitation Zone" were recommended to transfer to a resettlement area but were uneasy because they did not want to be transferred from a landslide-prone area to a "storm surge-prone area." From fears of getting buried by soil again, they now have to fear the possibility of drowning in the waters (Sunstar Cebu 2018). Aside from these fears, residents did not want to relocate to areas far from their place of residence because their source of livelihood is threatened. To address this dilemma, it is possible to combine probabilistic hazard maps for floods, shallow landslides, and storm surges and still find

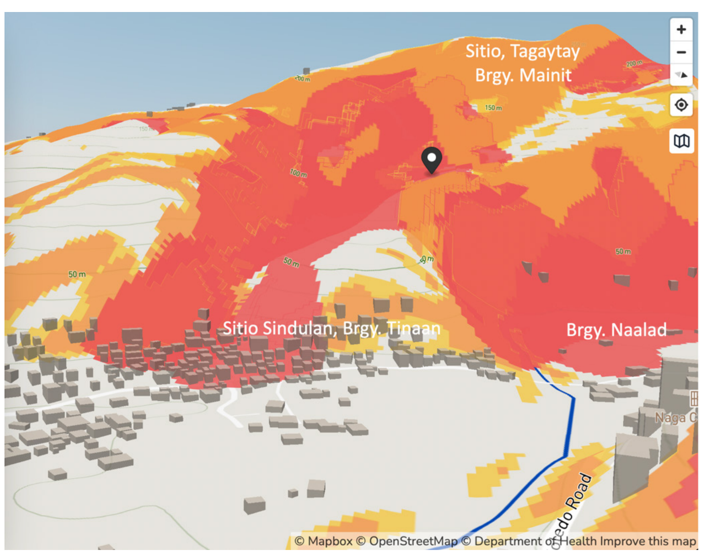

Figure 6. Landslide hazard map prepared in 2014. This is displayed in 3D in the NOAH website. Sitio Sindulan, Brgy Tinaan, and Brgy, Naalad are where most of the casualties were buried alive (UP NOAH Center n.d.). Red, orange and yellow colors represent high, medium and low landslide hazards, respectively

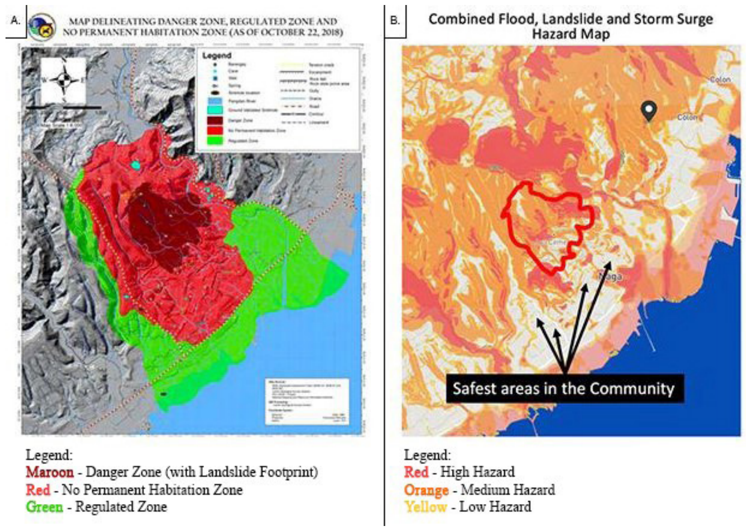

Figure 7. (A) Map delineating danger zone, regulated zone, and no permanent habitation zone (Mines and Geosciences Bureau 2018). (B) Combined post-disaster flood, landslide, and storm surge hazard maps generated by Project NOAH. The red outline is the landslide footprint, whereas the white arrows point to "relatively safe areas" near ground zero of the Naga City landslide disaster. (UP NOAH Center n.d.).

places that are habitable and relatively safe from threats of natural hazards (Figure 7B). Using this advanced simulation method allows the identification of nearby relocation sites that are acceptable to residents affected by the calamity. The experience at Naga City, Cebu, highlights the fact that the business of hazard mapping is not just to identify the hazards per se but should focus on finding the "safest places" in a community for relocation. This framework applies also to siting evacuation centers and land use development.

Other cases

There are many other disasters that happened over the past several years where more sophisticated risk assessment methods could have helped identify hazardous areas and the safest places in the community. These are the Tropical Storm Usman and Vinta disasters that happened in Bohol and Lanao del Norte, respectively (Lagmay and Racoma 2019), the Typhoon Ompong disaster in 2018 that buried people who sought refuge in a place they thought was safe from landslides and the disaster during Typhoon Rosita where landslides buried the Department of Public Works and Highways headquarters in Natonin, Mountain Province. The 2018 disaster in Natonin prompted Secretary Villar to issue a memorandum in 2018 to use probabilistic hazard maps of DOST-Project NOAH before constructing critical facilities (DPWH 2018). The latest disaster transpired at Brgy. Kusiong, Maguindanao, during Typhoon Paeng. Post-disaster images of Brgy. Kusiong reveal that the resettlement area was overwhelmed by massive floods and debris flows. A comparison of the MGB map for landslide and flood hazards (Figure 8A) against a model simulation of debris flows (Figure 8B) confirms the reliability of probabilistic simulations to predict impacted areas that have never been experienced by residents of the community.

D. Cases where Probabilistic Maps Were Utilized

In 2014, 100-year rain-return probabilistic flood hazard maps were produced along with landslide and storm surge hazard maps for 171 cities and municipalities affected by typhoon Haiyan. This was accompanied by the Joint DENR-DILG-DND-DPWH-DOST Memorandum Circular No. 2014-01 with the subject, "Adoption of Hazard Zone Classification in Areas Affected by Typhoon Haiyan and Providing Guidelines for Activities Therein". The hazard maps were prepared by DOST through Project NOAH, which at that time was the flagship program for disaster risk reduction of the Philippines. The 1:10,000

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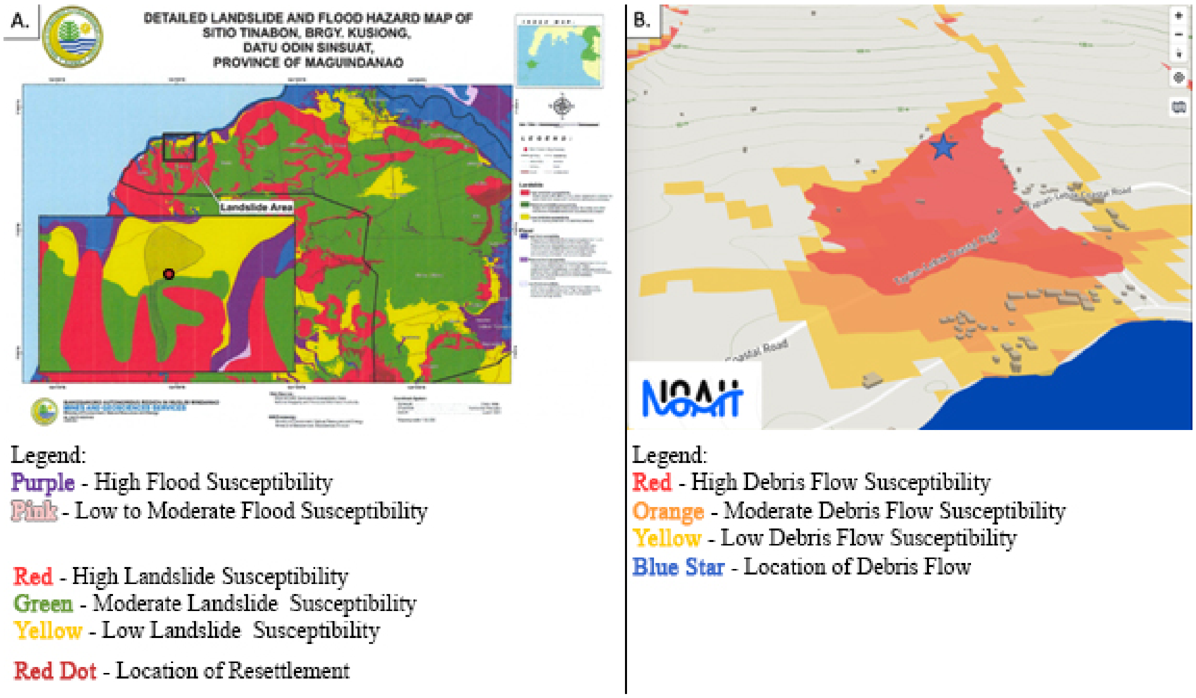

Figure 8. A) Detailed landslide and flood hazard map of Sitio Tiabon, Brgy. Kusiong, Datu Odin, Sinsuat, Province of Maguindanao (Mines and Geosciences Services – MENRE BARMM 2022). The place where the settlement was overwhelmed by debris flows (red dot) is depicted as a low landslide susceptible area (refer to map legend). B) The model simulation of debris flow hazards in the area of Kusiong, Datu Odin, Sinusuat. The blue star marks the place where the disaster happened (UP NOAH Center n.d)

scale hazard maps were based mainly on the output of Project NOAH, which is still openly available from the http://noah.up.edu.ph website. The flood, landslide, and storm surge hazard maps were printed as A0 size posters through funds from UNDP and distributed to the LGUs of the Yolanda Corridor. However, the distribution of the hazard maps was not systematically mainstreamed into the comprehensive development plans, disaster risk reduction management plans, and local climate change action plans of the local government units.

The flood hazard maps provided for the Yolanda Corridor following the Joint DENR-DILG-DND-DPWH-DOST Memorandum Circular No. 2014-01, were for a 100-year rain-return period. Although probabilistic in nature, the maps did not reflect future rain conditions due to climate change as described in the Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5 (AR5). The first attempt to use the probabilistic approach with a climate change lens (Lagmay et.al 2017) was made in the ADB project entitled, "Emergency Assistance and Early Recovery for Poor Municipalities Affected by Typhoon Yolanda'' (ADB 2017). Beneficiaries for this project were 30 municipalities of Leyte and Samar. The ADB Project was followed by the ReBUILD Project which was for Resilience Capacity Building for Cities and Municipalities to Reduce Risks from Climate Change and Natural Hazards. This project, which used probabilistic flood, storm surge, and shallow landslide hazard maps, was a collaborative effort of the Climate Change Commission (CCC), the United Nations Development Program (UNDP), and the University of the Philippines (UP). It was funded by the New Zealand AID Programme (Arquiza, 2018, UPNIGS 2018). The municipalities of Dumanggas and Zarraga in Iloilo, the city of Passi in Iloilo, the city of Tuguegarao, and the municipality of Iguig in Cagayan made use of probabilistic hazard maps with climate change projections for their climate and disaster risk assessment (CDRA). Other cities and municipalities that utilized similar probabilistic hazard maps for their CDRA and other local development plans, include: Taysan and Padre Garcia, Batangas, Naga City, Cebu, Science City of Munoz, Balanga, Bataan, City of Manila, and Quezon City.

V. SUMMARY AND CONCLUSIONS

Climate change scientists agree that global warming will cause typhoons to intensify, delivering more rain and stronger winds, which in turn would cause bigger floods, landslides, and storm surges that would impact communities. Scientists are also in agreement that these high-impact events will become more frequent. To anticipate these projected adverse impacts of climate change in the response plans of communities, it is vital to create climate change scenarios of hazards using probabilistic models, which involve multiple scenarios for each type of hazard (i.e., flood, landslide, and storm surge). This method called the **probabilistic risk assessment approach**, is recommended by the UNDRR (UNISDR 2017a), advocated as a development strategy in the Philippine Development Plan 2017-2022 (NEDA 2017), and Philippine Development Plan 2023-2028 (NEDA, 2023) and is the policy for Climate Change Adaptation of the Climate Change Commission (CCC Resolution No. 2019-001). However, the probabilistic risk assessment approach is not implemented on a nationwide scale despite being recognized internationally as a best practice.

We must learn from our mistakes from past disasters. One important feature of disasters in the Philippines is that it always takes us by surprise because we failed to anticipate them. Thus, survivors of disasters always say, “this is the first time a hazard of this magnitude happened in our place,” “we have never experienced this type of deluge,” or “we did not expect this to happen”. To address this repeating problem of the lack of anticipation, **probabilistic risk assessment** is necessary because multi-scenarios of floods, landslides, and storm surges can depict hazards bigger than that of the historical record or what people have experienced, including scenarios that reflect climate change. The Probabilistic Risk Assessment approach, as contained in CCC resolution 2019-001, is imperative to planning communities as it anticipates future hazards that are worse than what we know and is a requirement for Climate Change Adaptation for every city and municipality of the country. It is important for siting evacuation centers and must be mainstreamed in the plans of the community to attain the desired sustainable development goals of Filipinos. There is much that we can do and all we need is to systematically implement policies already in place.

Contributions of Authors:

- A.Lagmay devised the project, the main conceptual ideas and outline.
- J.Agapito, M.Rosales, A.Pascual, and C.Concepcion investigated deaths and damages in relation to hydrometeorological hazards that impacted the Philippines and extracted relevant data.
- A.Lagmay J.Agapito, M.Rosales, A.Pascual, and C.Concepcion analyzed and interpreted data on deaths and damages in relation to hydrometeorological hazards that impacted the Philippines.
- J.Agapito, M.Rosales, A.Pascual, and C.Concepcion produced graphical representations of the extracted data on hydrometeorological hazards that impacted the Philippines.
- J.Agapito, M.Rosales, A.Pascual, and C.Concepcion enhanced the legends of existing hazard maps for clarity.
- A.Lagmay wrote the manuscript with input from J.Santiago, J.Mendoza, J.Suarez, J.Agapito,
- Rosales, A.Pascual, and C.Concepcion.
- A. Lagmay led in researching and compiling literature for the manuscript with participation from
- Santiago, J.Mendoza, J.Suarez, J.Agapito, M.Rosales, A.Pascual, and C.Concepcion.
- J.Santiago, J.Mendoza, J.Suarez was responsible for hazards assessment and planning discussions. They also assisted in proofreading and typesetting.
- J.Santiago, J.Mendoza, J.Suarez assisted in ensuring the literature review and references for risk assessments used for planning were complete.

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The authors declare no conflict of interest or competing interest in the conduct and/or publication of this research work.

Data availability:

The data in this publication are from various reports cited by the authors and can be made available upon request.

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