PHILIPPINES CATASTROPHE RISK ASSESSMENT AND MODELING

COUNTRY RISK PROFILE: THE PHILIPPINES

The Philippines is expected to incur, on average, 206 billion PHP per year in damage to modeled assets due to earthquake ground shaking, tropical cyclone induced wind and precipitation, and non-tropical cyclone induced precipitation. In the next 25 years the Philippines has a 40% chance of experiencing a loss exceeding 840 billion PHP and casualties greater than 70 thousand people, and a 10% chance of experiencing a loss exceeding 2,000 billion PHP and casualties greater than 95 thousand people.

January 2014 DRAFT

OVERVIEW

AIR Worldwide Corporation (AIR) and the Asian Disaster Preparedness Center (ADPC) have prepared a natural catastrophe risk assessment study that provides a comprehensive view of the risk associated with earthquake ground shaking, tropical cyclone wind and precipitation, and non-tropical cyclone precipitation for the Philippines. This study is a joint initiative between the Department of Finance (DoF) of the Government of Philippines (GoP) and the World Bank (WB), with financial support from the Global Facility for Disaster Reduction and Recovery (GFDRR) and technical support from Geoscience Australia (GA). The risk profile for the Philippines has been developed to help the country mitigate their natural catastrophe risk.

RISK ASSESSMENT METHODOLOGY

The catastrophe models used to perform the risk analyses for the Philippines adopt the state-of-the-art methodology summarized in Figure 1. Every step of the methodology is heavily based on data collected specifically for the region. In addition, every step of the methodology is validated with historical observations when available. Furthermore, the entire risk assessment study has been peer reviewed by a team of scientists at Geoscience Australia (GA).

This study considers the devastating effects of wind and precipitation induced by tropical cyclones (typhoons) as well as flooding from non-tropical cyclone (NTC) induced precipitation (such as rainstorms and monsoons). Note that the NTC precipitation model developed in this study is not a full riverine flood model and thus may not capture all the effects of river-based floods. The study also considers the effects of earthquake ground shaking. Earthquakes, tropical cyclones, and floods are among the most prominent natural hazards in the Philippines. Other natural hazards found in the Philippines, such as volcanic eruptions and tsunamis, as well as secondary perils such as landslides and storm surge, are not explicitly modeled in this study. The risk due to weather phenomena is computed assuming current climate conditions. The effects of climate change on the risk assessment, which can be addressed using a similar methodology, can be analyzed in future investigations.

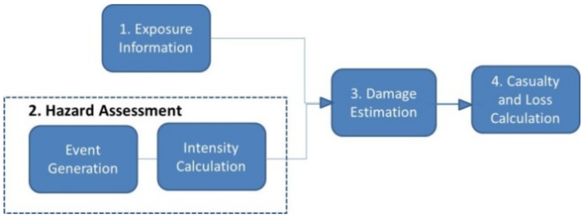


Figure 1: Risk modeling methodology.

EXPOSURE INFORMATION

The initial step of the risk analysis process shown in Figure 1 is the characterization of the assets and distribution of population exposed to natural hazards. The 2013 projected population of the Philippines is estimated at 98.2 million people. A GIS-based population database was compiled in order to geographically identify the population most at risk in the Philippines. This database, which was developed mainly from official census data, provides population counts and additional information by province and by municipality/city.

An industry exposure database (IED) that includes a comprehensive inventory of private residential, commercial, and industrial buildings in the Philippines has been developed. The IED includes the building location, replacement cost, and structural and non-structural characteristics (e.g. number of stories, occupancy class, and construction class) that influence the vulnerability to natural perils. The spatial distribution of the estimated 24.2 million risk counts (dwellings and business establishments) in the database covers all known major built-up areas and structures ranging from informal dwellings to masonry houses to high-rise office buildings. The database was assembled using a variety of information including official data from the Philippines National Statistics Office and several GIS-based datasets. The IED is also referred to as the private building exposure database. Figure 2 illustrates the distribution of the modeled private building exposure.

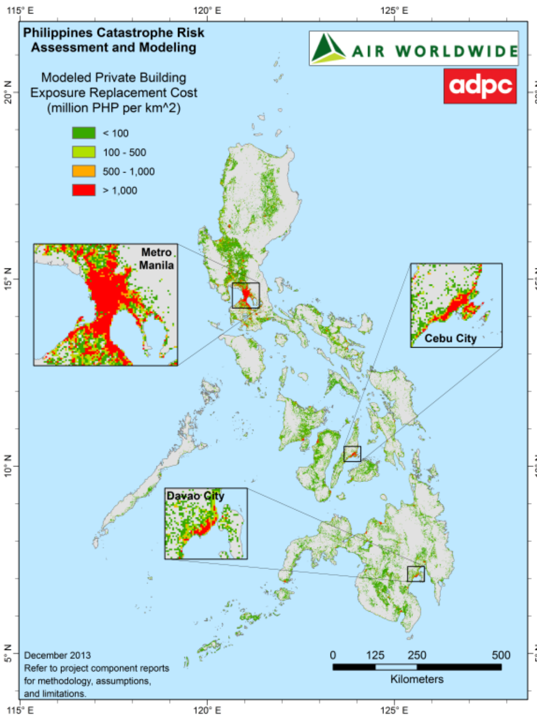


Figure 2: Distribution of modeled exposure of private properties.

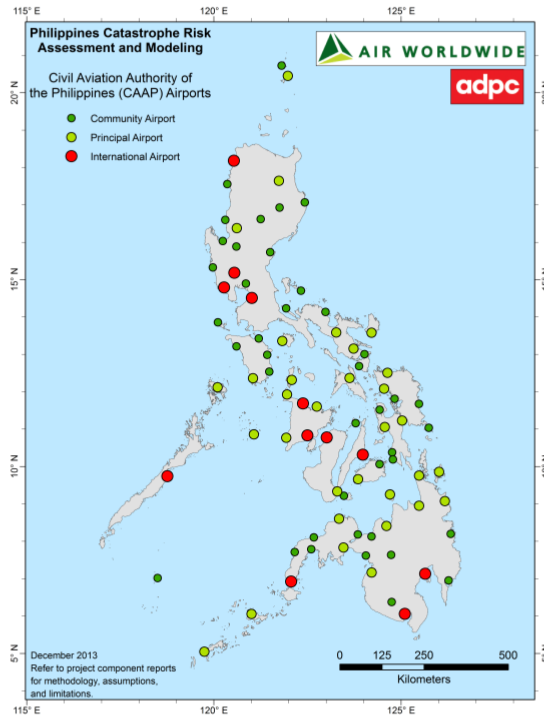


Figure 3: Location of CAAP Airports in the Philippines.

A national government asset database that comprises a detailed and extensive inventory of government assets in the Philippines (including public schools, public hospitals, as well as major infrastructure such as ports, airports, bridges, and roads) has also been developed. As an example, Figure 3 shows the location and class of all government owned Civil Aviation Authority of the Philippines (CAAP) Airports in the Philippines. In addition to their locations, the government asset database also includes structural and non-structural characteristics as well as estimates of the replacement costs of such assets. Most of the raw data used for the development of the database was obtained directly from official agencies in the Philippines (such as the Department of Public Works and Highways and the Department of Education) or compiled from various sources available in the public domain.

The millions of private buildings and government assets with their characteristics, estimated value, and location are included in a geo-referenced database. While the private buildings exposure database is proprietary to AIR, the government assets database has been released to the WB. ***The estimated total building replacement cost (in 2013 currency value) of all the assets modeled in this study is about 24,798 billion PHP, an amount that comprises 22,085 billion PHP in private buildings and 2,712 billion PHP in government assets.*** Figure 4 shows the estimated replacement cost density for all modeled assets by province. Table 1 summarizes the population and the inventory of private buildings and government assets (or "exposure") at risk as well as key economic values for the Philippines.

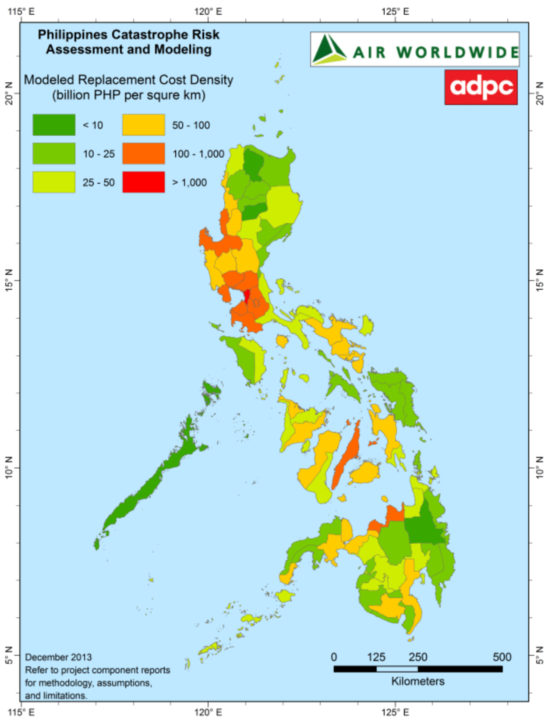


Figure 4: Estimated replacement cost density for all modeled assets by province.

Table 1: Summary of Exposure in the Philippines for the Year 2013

General Information	
Total Population (Million):	98.247
GDP Per Capita (PHP):	116,085
Total GDP (Billion PHP):	11,405
Estimated Cost of Replacing Assets (Billion PHP)	
Modeled Private Buildings:	22,085
Modeled Government Assets:	2,712
Total Modeled Assets:	24,798
Government Revenue and Expenditure	
Total Government Revenue	
(Billion PHP):	1,584
(% GDP):	13.9%
Total Government Expenditure	
(Billion PHP):	1,188
(% GDP):	10.4%
Exchange Rate	
PHP to USD:	0.023

Note: Values other than population and replacement cost estimates are assembled and trended to 2013 from the World DataBank.

HAZARD ASSESSMENT

The estimation of the hazard is the second building block in the risk assessment methodology shown in Figure 1. The Philippines is one of the most prone countries to natural hazards in the world. The Philippines is located in the Northwest Pacific Tropical Cyclone Basin, known for frequent occurrence of tropical cyclones (also known as typhoons) with consequent damaging winds and rains. Considering the historical record, an average of about 27 tropical cyclones occur in the basin each year, including about seven that make landfall in the Philippines, with most activity occurring between May and December. These tropical cyclones typically cause considerable damage and destruction to the Philippines every year. For example, Tropical Storm Thelma in 1991 (also known as Tropical Storm Uring in the Philippines), while relatively low in intensity, was one of the deadliest tropical cyclones in Philippine history, with at least 5,000 deaths, mainly due to intense flooding. Super Typhoon Angela (Rosing) in 1995 brought catastrophic devastation over the Metro Manila, Calabarzon, and Bicol Regions. More recent catastrophic events include Super Typhoon Bopha (Pablo) in 2012 which devastated the Philippines' southern region and Super Typhoon Haiyan (Yolanda) in 2013 which caused catastrophic destruction in the Visayas. Haiyan is one of the most intense storms on record globally and consequently one of the most devastating tropical cyclones ever to affect the Philippines on record.

The tracks and maximum intensity of historical tropical cyclone activity for the last 60 years are shown in Figure 5. Many of these storms have impacted one or more regions of the Philippines, causing widespread destruction, high economic losses, and significant casualties (injuries and fatalities). The catalog of historical storms was assembled from the International Best Tracks Archive for Climate Stewardship (IBTrACS) project dataset, which is endorsed by the World Meteorological Organization (WMO). This includes data from meteorological agencies across the region. Specifically, Figure 5 shows data from 1951 to 2011 provided by the Regional Specialized Meteorological Center (RSMC) Tokyo, the official reporting agency for the basin.

Figure 6 shows the average levels of wind speed, by province, due to tropical cyclones that have about a 40% chance to be exceeded at least once in the next 50 years (i.e., a 100 year mean return period). Wind speeds greater than about 65 km/hr are capable of generating damage to buildings with consequent economic losses.

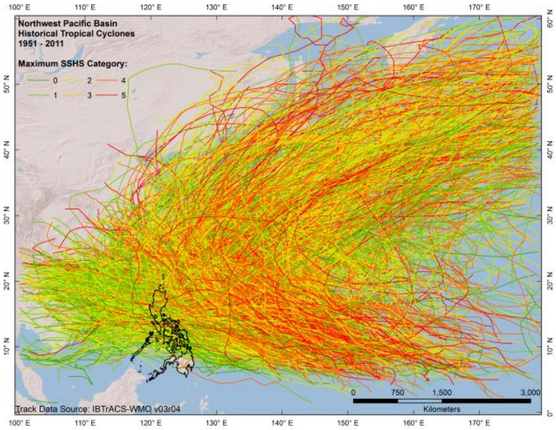


Figure 5: Tracks of the over 1,600 historical tropical cyclones in the Northwest Pacific Basin in the last 60 years (1951-2011).

The Philippines is situated along the Pacific "Ring of Fire", which aligns with the boundaries of major tectonic plates. These boundaries contain active seismic zones capable of generating large earthquakes. Furthermore, the Philippines is located near active subduction zones, which are capable of generating major earthquakes (including those greater than magnitude 8) and large tsunamis. Some of the most devastating earthquake events include the 1976 Moro Gulf earthquake, which resulted in severe shaking in the southern region of the Philippines along with a destructive tsunami, and the 1990 Luzon earthquake which resulted in over 1,600 fatalities causing significant damage throughout a very large area in the northern region of the Philippines. More recently, the 2013 Bohol earthquake affected the Central Visayas region, resulting in over 200 fatalities and damaging or destroying tens of thousands of structures.

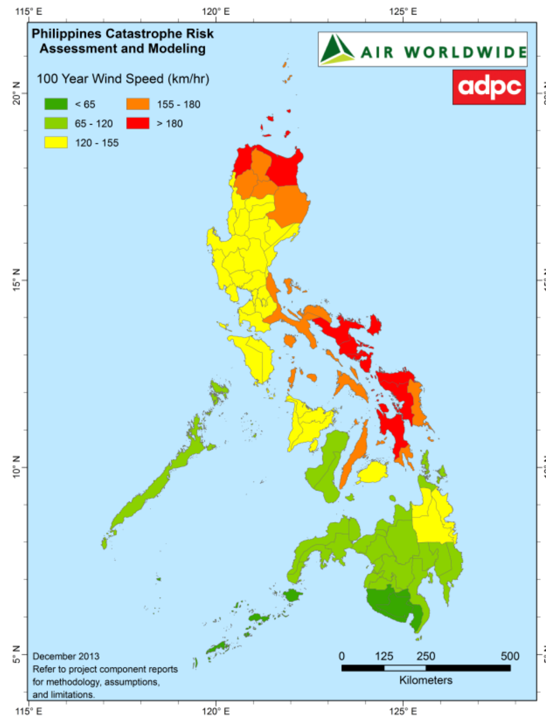


Figure 6: Average maximum one-minute sustained wind speed (in kilometers per hour), on average by province, with a 40% chance to be exceeded at least once in the next 50 years (i.e., 100 year mean return period).

Earthquake records are available dating back to the 16th century, and about 8,000 earthquakes with magnitude 5.0 or greater have been reported in the region historically, with over 100 earthquakes with magnitude 7.0 or greater. Figure 7 shows the locations and magnitudes of all major earthquakes on record.

Figure 8 shows the levels of ground shaking due to earthquakes that have about a 40% chance to be exceeded at least once in the next 50 years (i.e., a 100 year mean return period). Peak ground accelerations greater than about 0.05g are capable of generating damage to buildings with consequent economic losses.

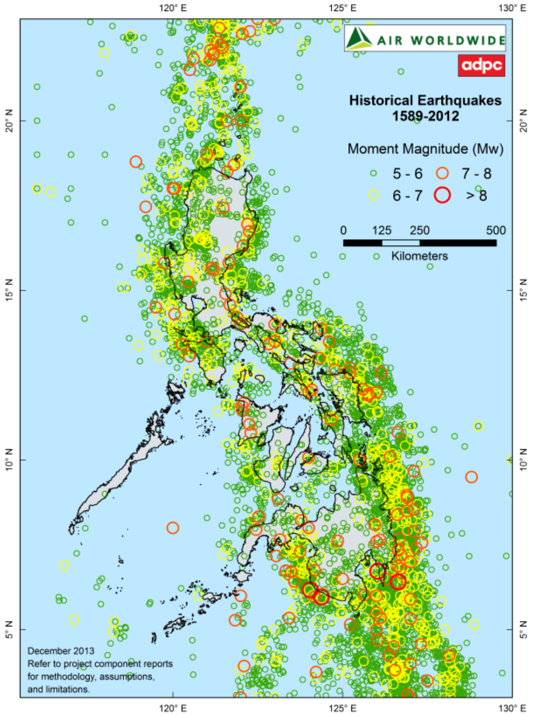


Figure 7: Epicenters of approximately 8,000 large earthquakes that were reported from 1589 to 2012. The earthquake data is assembled from several sources.

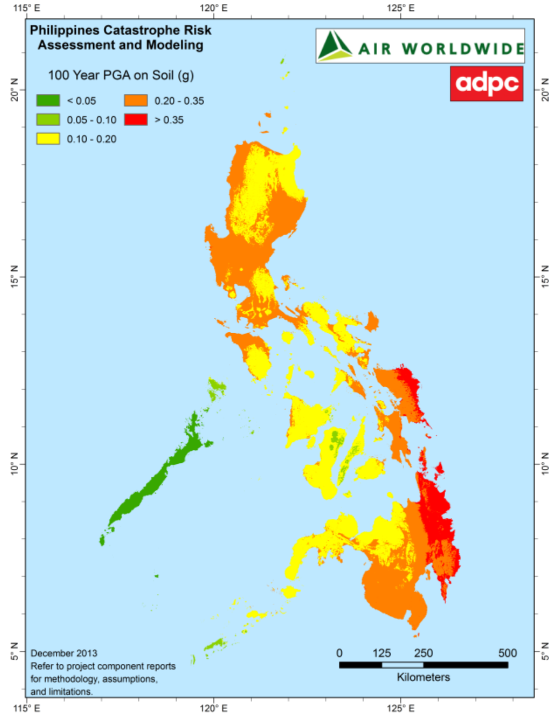


Figure 8: Peak horizontal acceleration of the ground (note: 1g is equal to the acceleration of gravity) that have about a 40% chance to be exceeded at least once in the next 50 years (i.e., a 100 year mean return period).

The climate of the Philippines is generally classified as tropical and is characterized by relatively high temperature, intense humidity, and significant rainfall. The summer monsoon brings heavy rains to most of the Philippines from May to October. Monsoon rains are typically intense and are not normally associated with high winds or storm surge. The heaviest rainfall in the Philippines typically occurs during the months of March to October, which can result in devastating floods. Note that floods can result both from tropical cyclones and from rain not associated with tropical cyclones. In this study, flooding due to precipitation (rain) <u>not</u> associated with tropical cyclones is referred to as flooding from non-tropical cyclone (NTC) induced precipitation. Significant historical flood events not generally associated with tropical cyclones include the Great Flood of 1972, which was caused by weeks of heavy rainfall and inundated much of Central Luzon. More recently, the 2012 Philippine Floods, which resulted from a strong movement of the southwest monsoon, lead to death and destruction in several regions across the Philippines including Manila.

The frequency and occurrence of non-tropical cyclone induced precipitation can be examined by comparing total annual rainfall data, such as that from the Tropical Rainfall Measuring Mission (TRMM), with rainfall data from known tropical cyclone events. Figure 9 shows the average annual non-tropical cyclone (NTC) induced rainfall, by province, determined from the Tropical Rainfall Measuring Mission (TRMM) data.

The spatial and temporal occurrence and severity of past events have been used as a guide to simulate potential tropical cyclones, earthquakes and non-tropical cyclone induced precipitation that may affect the Philippines in the future. This step is called “Event Generation” as shown in Figure 1. The simulated events are not necessarily identical to those that occurred in the past but are statistically consistent.

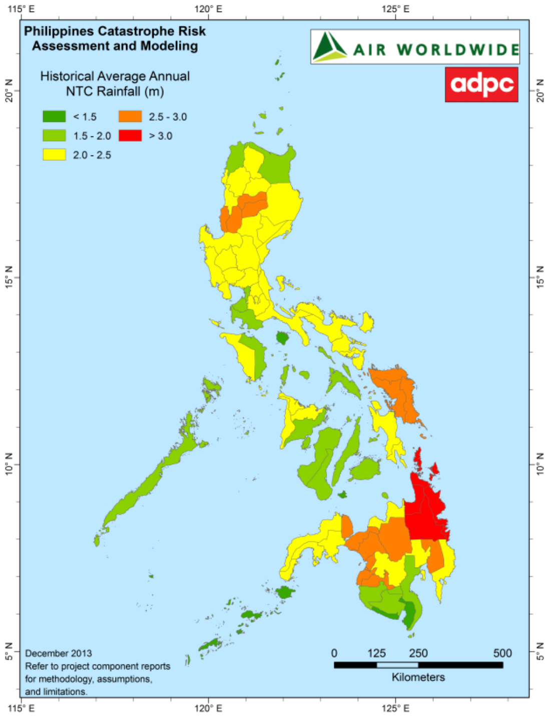


Figure 9: Average annual non-tropical cyclone (NTC) induced rainfall, by province, determined from the Tropical Rainfall Measuring Mission (TRMM) data.

The catalog of simulated natural catastrophe events, which spans a large region around the Philippines, contains more than 293 thousand tropical cyclones, more than 775 thousand earthquakes, and more than 118 thousand non-tropical cyclone induced precipitation events grouped in 10,000 potential realizations of what may happen in the next year.

Mathematical models are then used to estimate the intensity of the simulated events in the affected region (see "Intensity Calculation" in Figure 1). These effects are wind and precipitation for tropical cyclones, ground shaking for earthquakes, and flooding for non-tropical cyclone induced precipitation. The models are based on empirical data and on the underlying physics of the phenomena. For example, the severity of ground shaking given an earthquake event can be estimated using ground motion prediction equations (GMPEs). Current GMPEs are highly sophisticated and consider several factors, including the magnitude of the event, the distance from the event to the site location, the style of earthquake faulting, and local site-conditions that may amplify the level of shaking.

DAMAGE ESTIMATION

The third step in the risk assessment procedure displayed in Figure 1 deals with damage estimation, a task that requires determining the vulnerability of the assets at risk and the probable casualty rates for occupied structures that are damaged by wind, rain, flooding, or ground shaking.

All of the modeled assets in the exposure database have been categorized in distinct groups of similar vulnerability to earthquakes, tropical cyclones, and flood (e.g., single-story wood frame houses, high-rise concrete apartments, and bridges, etc.). The vulnerability of different asset types was derived from engineering analyses, corroborated with damage assessments and loss data from past events in the region, when available. The vulnerability is measured by a relationship that provides the expected loss of an asset subjected to different levels of ground shaking, wind speeds, or precipitation. The loss, which reflects the cost of repairing the damaged asset, is usually expressed as a percentage of the replacement cost of the asset. For example, in the damage function shown in Figure 10, a one-minute sustained wind speed of 220 km/hr is expected to cause, on average, moderate to major damage that will take about 30% of the total replacement cost of the asset to repair.

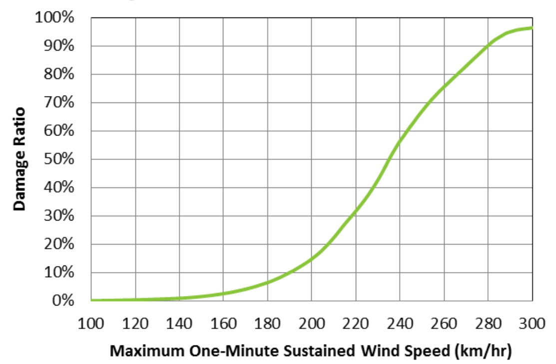


Figure 10: Average relationship between wind speed and expected level of damage (repair cost ratio) for a typical building in the Philippines.

In addition to deriving vulnerability relationships that link the intensity of an event to losses from damage, models were also developed to estimate the number of casualties (fatalities and injuries) caused by each type of event. The earthquake ground-shaking casualty model estimates casualties as a function of the shaking intensity and the number of people exposed to such intensities. The tropical cyclone and flood casualty model predicts the number of casualties as a function of economic losses, which are used as a proxy for the number of damaged buildings. All three models are heavily based on empirical data specific to the Philippines.

CASUALTY AND LOSS CALCULATION

The risk profile for the Philippines expresses the likelihood of adverse consequences due to natural catastrophes that will occur within a certain time frame (for example, in the next year or in the next 50 years). The risk profile is developed in the risk module. The adverse consequences are measured in terms of economic losses and by the number of casualties (injuries and fatalities) among the affected population.

The modeled economic losses reflect both the cost needed to repair or replace the damaged assets, and the emergency losses that the local and national government may sustain as a result of providing necessary relief and undertaking recovery efforts. Such efforts include debris removal, setting up shelters for those made homeless, or supplying medicine and food. In this study, emergency losses have been estimated as a fraction of the direct losses from damage. Research on past natural catastrophe events has revealed that an average estimate of the emergency losses, as a percentage of the direct losses suffered by residential dwellings, commercial establishments, public buildings, schools, and hospitals, is about 16% for earthquake ground shaking and 23% for tropical cyclones and flood. These percentages were applied in this study.

RISK ANALYSIS RESULTS

The natural catastrophe risk profile for the Philippines is derived from the estimated impact for all the simulated future events on the modeled exposure. For each event of a given location and severity (e.g., a magnitude 8 earthquake occurring in the southern region of the Philippines), the local intensity (e.g., the peak horizontal acceleration of the ground estimated at the location of each modeled asset in the affected area) is calculated using the mathematical models previously outlined. The level of damage and loss for any given asset at any given location in the affected area are estimated based on the specific characteristics of the asset (e.g., a low-rise timber frame house) and on the level of intensity predicted at that location (e.g., a peak horizontal acceleration equal to 30% of gravity). The total losses for any simulated event are equal to the sum of the losses at all locations affected by that event. The estimation of casualties caused by any event is done in a similar fashion. The loss and casualty calculations are repeated for each of the simulated events (293 thousand tropical cyclones, 775 thousand earthquakes, and 118 thousand non-tropical cyclone induced precipitation events) in the region, which represent 10,000 potential realizations of next-year activity. The risk profiles are obtained by ranking the losses and casualties from all the simulated events.

The country's risk profile is derived from an estimation of the direct losses that all the simulated potential future events generate due to damage of the modeled exposure, which includes private buildings and government assets. The direct losses comprise the cost of repairing or replacing the damaged assets but do not include other non-modeled losses such as contents losses, business interruption losses, and losses to non-modeled assets such as agriculture buildings and crops. The direct losses for tropical cyclones are modeled from wind and rain damage, for earthquakes they are modeled from ground shaking damage, and for non-tropical cyclone induced precipitation they are modeled from water damage. After assessing the cost of repairing or rebuilding the damaged assets due to the impact of all the simulated potential future events, it becomes possible to estimate in a probabilistic manner the severity of losses for future catastrophes.

The simulations of possible next-year tropical cyclone, earthquake, and non-tropical cyclone induced precipitation activity show that some years will see no events affecting the Philippines, while other years may see one or several events affecting the region, similar to what has happened historically. The annual losses to modeled assets averaged over the many realizations of next-year activity are shown in Figure 11 separately for tropical cyclone, earthquake, and non-tropical cyclone (NTC) induced precipitation, while the contributions to the average annual loss from the different provinces are displayed in absolute terms in Figure 12 and normalized by the total modeled asset value for each province in Figure 13. Figure 13 shows how the relative risk varies by province across the country.

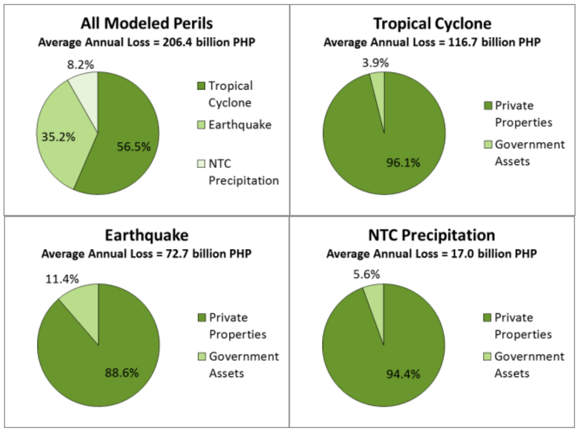


Figure 11: Average annual loss due to tropical cyclone wind and rain, earthquake ground shaking, and flooding from non-tropical cyclone induced precipitation along with its contribution from the two types of modeled assets.

In addition to focusing on the average risk per calendar year, one could also focus on large and rather infrequent but possible future losses within a given year. Table 2 summarizes the risk profile for the Philippines in terms of both direct losses and emergency losses. The former are the expenditures needed to repair or replace the damaged assets while the latter are the expenditures that the Philippine government may need to incur in the aftermath of a natural catastrophe to provide necessary relief and conduct activities such as debris removal, setting up shelters for homeless or supplying medicine and food.

Table 2 includes the modeled losses that are expected to be exceeded, on average, once every 50, 100, and 250 years. For example, an ***earthquake modeled loss exceeding about 1,000 billion PHP, which is equivalent to about 9.2% of the Philippines's GDP, is to be expected, on average, once every 100 years***. In the Philippines, the risk analysis indicates that tropical cyclone losses are more frequent than losses due to earthquake ground shaking, although the loss potential for severe, less frequent events is higher for earthquake ground shaking. Flooding from non-tropical cyclone induced precipitation poses a relatively smaller financial risk but remains potentially catastrophic.

A more complete picture of the risk can be found in Figure 14, which shows the mean return period of direct losses generated by earthquake, tropical cyclone, and non-tropical cyclone induced precipitation combined. The 50, 100, and 250 year mean return period losses in Table 2 can also be read off the plot in this figure. The direct losses are expressed both in absolute terms and as a percent of the national GDP.

Besides causing damage and losses to the built environment, future natural catastrophe events will also have an impact on population. The same probabilistic procedure described above for losses has been adopted to estimate the likelihood that different levels of casualties (i.e., fatalities and injuries) may result from the future occurrence of these events. As shown in Table 2, the model estimates, for example, that there is a ***40% chance in the next 50 years (100 year mean return period) that events in a calendar year will cause casualties exceeding 74 thousand people in the Philippines***. Events causing 100 thousand or more casualties in a calendar year are also possible but have much lower likelihood of occurring.

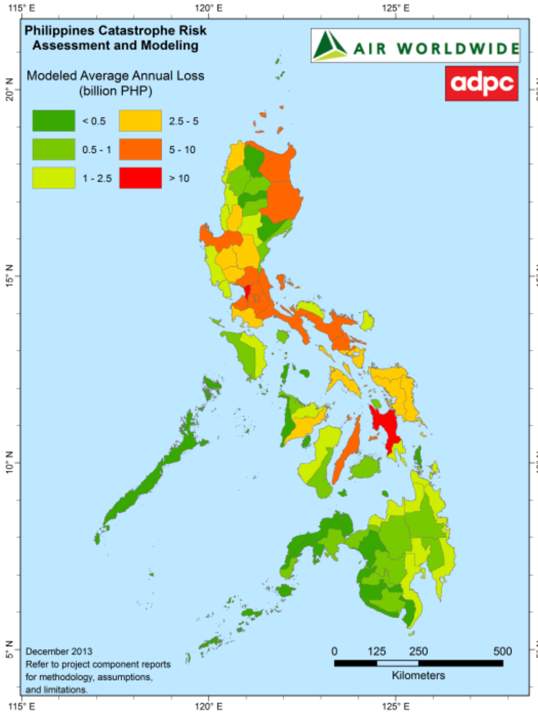


Figure 12: Contribution from the different provinces to the average annual loss for tropical cyclone wind and rain, earthquakes ground shaking, and flooding from non-tropical cyclone induced precipitation.

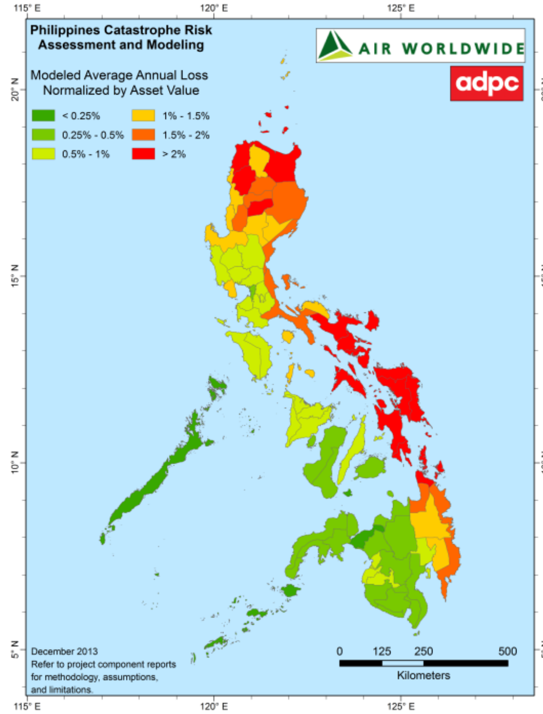
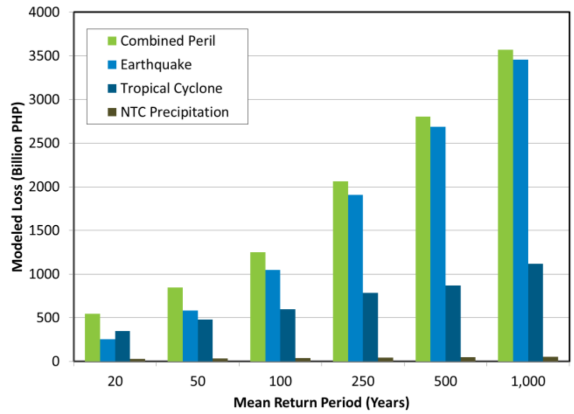


Figure 13: Contribution from the different provinces to the tropical cyclone wind and rain, earthquakes ground shaking, and flooding from non-tropical cyclone induced precipitation average annual loss divided by the replacement cost of the modeled assets in each Province.

Table 2: Natural Catastrophe Risk Profile for the Philippines

Mean Return Period (years)	AAL	50	100	250
Risk Profile: Tropical Cyclone				
Direct Losses				
(Billion PHP)	116.7	477.2	598.5	786.3
(% GDP)	1.0%	4.2%	5.2%	6.9%
Emergency Losses				
(Billion PHP)	26.8	109.8	137.7	180.8
(% of total government expenditures)	2.3%	9.2%	11.6%	15.2%
Casualties	13,420	54,877	68,827	90,422
Risk Profile: Earthquake				
Direct Losses				
(Billion PHP)	72.7	582.4	1,047.0	1,908.4
(% GDP)	0.6%	5.1%	9.2%	16.7%
Emergency Losses				
(Billion PHP)	11.6	93.2	167.5	305.3
(% of total government expenditures)	1.0%	7.8%	14.1%	25.7%
Casualties	881	8,408	14,830	28,571
Risk Profile: Non-Tropical Cyclone Induced Precipitation				
Direct Losses				
(Billion PHP)	17.0	35.0	38.2	44.2
(% GDP)	0.1%	0.3%	0.3%	0.4%
Emergency Losses				
(Billion PHP)	3.9	8.0	8.8	10.2
(% of total government expenditures)	0.3%	0.7%	0.7%	0.9%
Casualties	1,958	4,025	4,389	5,088
Risk Profile: All Modeled Perils				
Direct Losses				
(Billion PHP)	206.4	846.9	1,250.0	2,062.1
(% GDP)	1.8%	7.4%	11.0%	18.1%
Emergency Losses				
(Billion PHP)	42.4	167.0	225.8	341.2
(% of total government expenditures)	3.6%	14.1%	19.0%	28.7%
Casualties	16,260	60,909	74,130	95,528



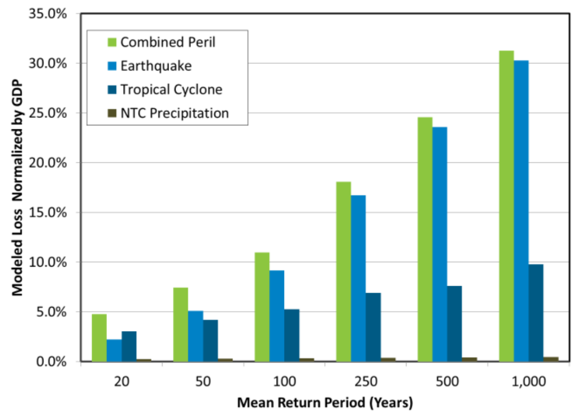


Figure 14: Direct modeled losses (in absolute terms and normalized by GDP) caused by tropical cyclones, earthquakes, and non-tropical cyclone (NTC) induced precipitation that are expected to be exceeded, on average, once in the time period indicated.

APPLICATIONS

The country risk profile can support multiple applications that benefit both public and private stakeholders. In ***urban and development planning,*** planners can use the risk profile information to identify the best location of new development areas, evaluate how natural hazards may shape their development, and to assess whether the benefits of reducing the risk of natural events justify the costs of implementing the risk mitigating measures. In addition, the risk profile can inform the development of ***disaster risk financing and insurance*** solutions and ***ex ante budget planning*** options to increase the financial resilience of the country against natural disasters while maintaining its fiscal balance. The earthquake and tropical cyclone hazard models can provide critical information to ***building codes*** about country-specific seismic and tropical cyclone induced wind loads that buildings could be designed for to ensure adequate shelter to the population. The risk information can also help identify existing vulnerable areas and communities located in or adjacent to these areas. This information can assist in supporting more targeted intervention in ***community-based disaster risk management and climate change adaptation*** actions. In the occurrence of a natural disaster the catastrophe models can provides extremely useful baseline data and information for conducting timely and effective ***post-disaster damage assessments***.