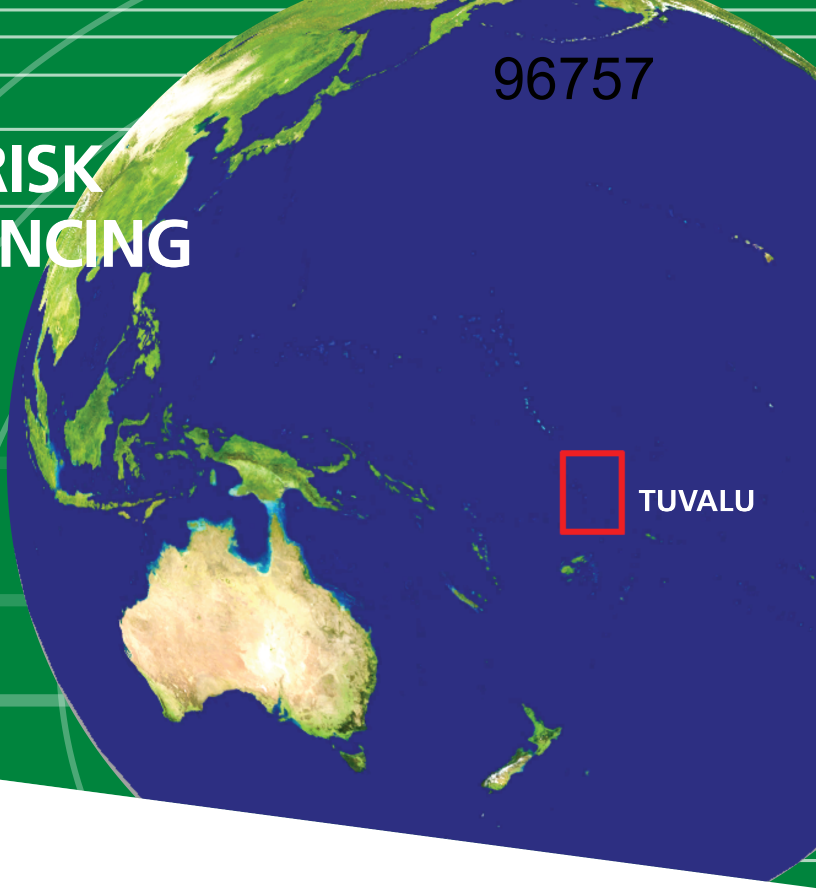
PACIFIC CATASTROPHE RISK ASSESSMENT AND FINANCING INITIATIVE



SEPTEMBER 2011

COUNTRY RISK PROFILE: TUVALU

Tuvalu is expected to incur, on average, 0.2 million USD per year in losses due to earthquakes and tropical cyclones. In the next 50 years, Tuvalu has a 50% chance of experiencing a loss exceeding 4 million USD and casualties larger than 15 people, and a 10% chance of experiencing a loss exceeding 9 million USD and casualties larger than 50 people.

POPULATION, BUILDINGS, INFRASTRUCTURE AND CROPS EXPOSED TO NATURAL PERILS

An extensive study has been conducted to assemble a comprehensive inventory of population and properties at risk. Properties include residential, commercial, public and industrial buildings; infrastructure assets such as major ports, airports, power plants, bridges, and roads; and major crops, such as coconut, palm oil, taro, vanilla and many others.

TABLE 1: Summary of Exposure in Tuvalu (2010)	
General Information:	
Total Population:	9,960
GDP Per Capita (USD):	3,213
Total GDP (million USD):	32.0
Asset Counts:	
Residential Buildings:	2,621
Public Buildings:	179
Commercial, Industrial, and Other Buildings:	218
All Buildings:	3,018
Hectares of Major Crops:	1,914
Cost of Replacing Assets (million USD):	
Buildings:	229
Infrastructure:	38
Crops:	1
Total:	268
Government Revenue and Expenditure:	
Total Government Revenue	
(Million USD):	45.4
(% GDP):	141.9%
Total Government Expenditure	
(Million USD):	42.9
(% GDP):	134.1%

[1] Data assembled from various references including WB, ADB, IMF and The Secretariat of the Pacific Community (SPC).
[2] The projected 2010 population was trended from the 2006 census using estimated growth rates provided by SPC.

Table 1 summarizes population and the inventory of buildings, infrastructure assets, and major crops (or "exposure") at risk as well as key economic values for Tuvalu. It is estimated that the ***replacement value of all the assets in Tuvalu is 268 million USD,*** of which about 85% represents buildings and 14% represents infrastructure.

Figures 1 and 2 illustrate the building exposure location and replacement cost distribution, respectively. The footprints of about 2,200 of the approximately 3,000 buildings shown in Figure 1 were digitized from high-resolution satellite imagery. About 1,000 of such buildings, all on the main island of Funafuti, were also field surveyed and photographed by a team of inspectors deployed for this purpose. Figure 3 displays the land cover/land use map that includes the location of major crops. The data utilized for these exhibits was assembled, organized and, when unavailable, produced in this study.

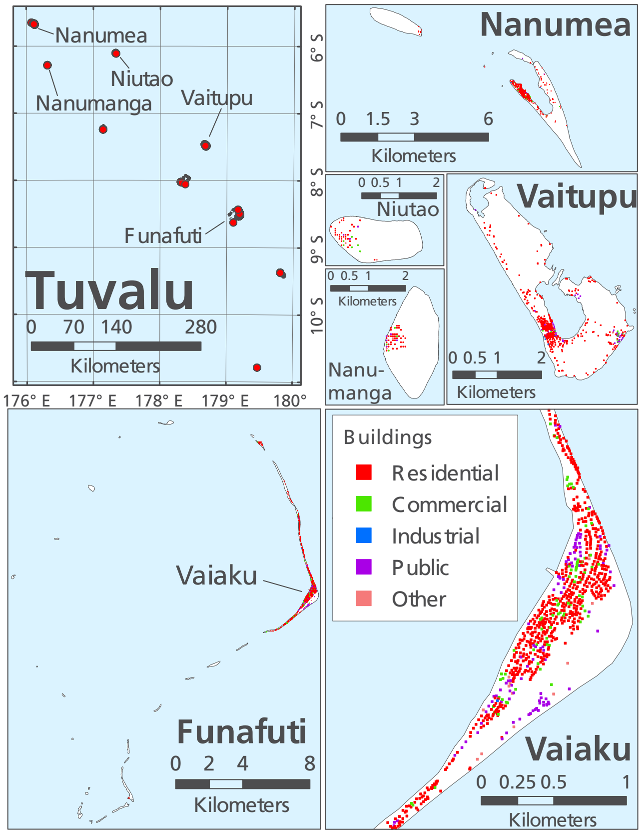


Figure 1: Building locations.

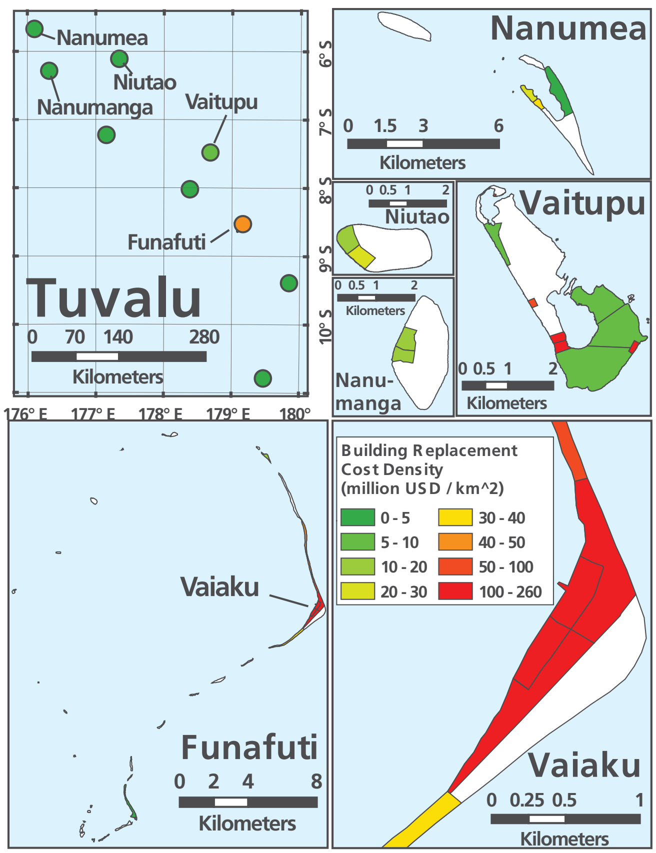


Figure 2: Building replacement cost density by village.

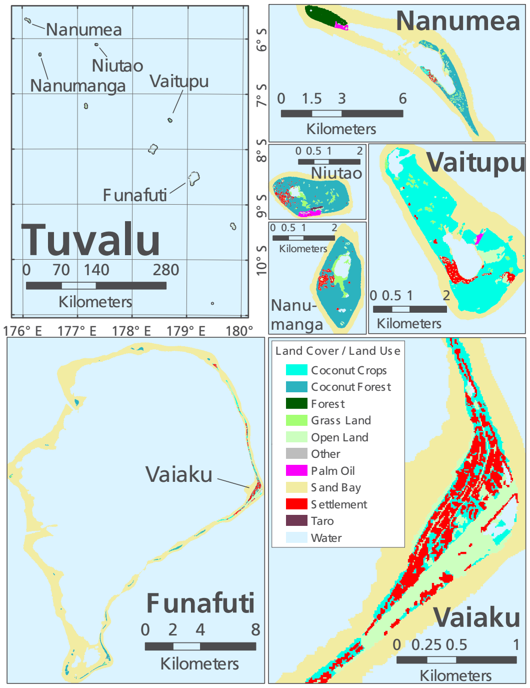


Figure 3: Land cover/land use map.

TROPICAL CYCLONE AND EARTHQUAKE HAZARDS IN TUVALU

The Pacific islands region is prone to natural hazards. Tuvalu is located south of the equator at the northern extremity of an area known for the frequent occurrence of tropical cyclones with damaging winds, rains and storm surge between the months of October and May. In the South Pacific region from the equator to New Zealand in latitude and from Indonesia to east of Hawaii in longitude, almost 1,000 tropical cyclones with hurricane-force winds spawned in the last 60 years, with an average of about 16 tropical storms per year. Tuvalu was affected by damaging cyclones multiple times in the last few decades. For example, in 1997 alone, Tuvalu was devastated by three tropical cyclones: Gavin, Hina, and Keli. Tropical cyclone Bebe in 1972 was one of Tuvalu's worst disasters in recent history and reportedly caused six fatalities. Figure 4 shows the levels of wind speed due to tropical cyclones that have about a 40% chance to be exceeded at least once in the next 50 years (100-year mean return period). These wind speeds, if they were to occur, are capable of generating moderate to severe damage to buildings, infrastructure and crops with consequent significant economic losses.

Tuvalu is situated in a relatively quiet seismic area but is surrounded by the Pacific "ring of fire," which aligns with the boundaries of the tectonic plates. These tectonic plate boundaries are extremely active seismic zones capable of generating large earthquakes and, in some cases, major tsunamis that can travel great distances. No significant earthquakes have been observed in recent history. However, in 1899, a large earthquake off the eastern coast of New Ireland, Papua New Guinea generated a large tsunami that

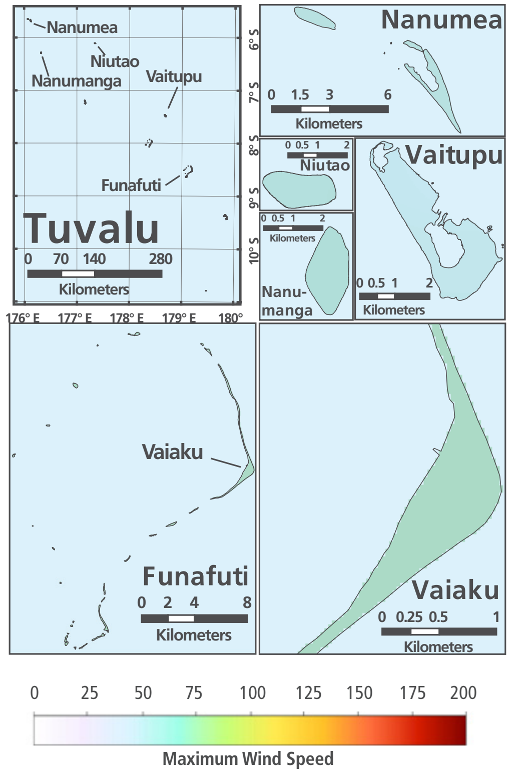
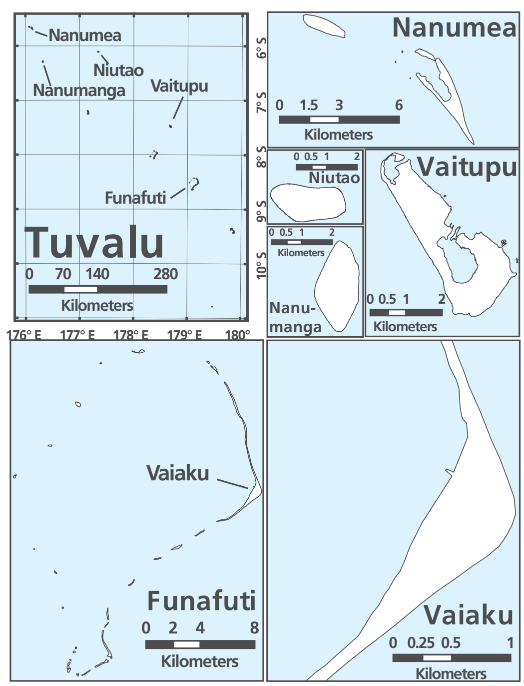


Figure 4: Maximum 1-minute sustained wind speed (in miles per hour) with a 40% chance to be exceeded at least once in the next 50 years (100-year mean return period).



Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	none	none	none	Very light	light	Moderate	Moderate/ Heavy	Heavy	Very Heavy
Peak ACC. (%g)	<0.17	0.17-1.4	1.4-4.0	4.0-9	9-17	17-32	32-61	61-114	>114
Peak Vel. (cm/s)	<0.12	0.12-1.1	1.1-3.4	3.4-8	8-16	16-31	31-59	59-115	>115
Instrumental Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Wald. et al: 1999

Figure 5: Peak horizontal acceleration of the ground (Note: 1g is equal to the acceleration of gravity) that has about a 40% chance to be exceeded at least once in the next 50 years (100-year mean return period).

resulted in destructive waves at Nukufetau atoll. Figure 5 shows that Tuvalu has a 40% chance in the next 50 years of experiencing, at least once, extremely weak levels of ground shaking. These levels of shaking are not expected to cause damage to well-engineered buildings and infrastructure assets.

RISK ANALYSIS RESULTS

To estimate the risk profile for Tuvalu posed by tropical cyclones and earthquakes, a simulation model of potential storms and earthquakes that may affect the country in the future was constructed. This model, based on historical data, simulates more than 400,000 tropical cyclones and about 7.6 million earthquakes, grouped in 10,000 potential realizations of the next year's activity in the entire Pacific Basin. The catalog of simulated earthquakes also includes large magnitude events in South and North America, Japan and the Philippines, which could generate tsunamis that may affect Tuvalu's shores.

The country's earthquake and tropical cyclone risk profiles are derived from an estimation of the direct losses to buildings, infrastructure assets and major crops caused by all the simulated potential future events. The direct losses include the cost of repairing or replacing the damaged assets but do not include other losses such as contents losses, business interruption losses and losses to primary industries other than agriculture. The direct losses for tropical cyclones are caused by wind and flooding due to rain and storm surge, while for earthquakes they are caused by ground shaking and tsunami inundation. After assessing the cost of repairing or rebuilding the damaged assets due to the impact of all the simulated potential future events, it is possible to estimate in a probabilistic sense the severity of losses for future catastrophes.

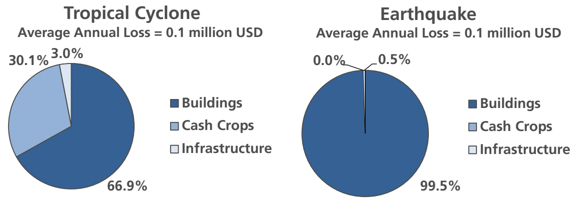


Figure 6: Average annual loss due to tropical cyclones and earthquakes (ground shaking and tsunami) and its contribution from the three types of assets.

The simulations of possible next-year tropical cyclone and earthquake activity show that some years will see no storms or earthquakes affecting Tuvalu, while other years may see one or more events affecting the islands, similar to what has happened historically. The annual losses averaged over the many realizations of next-year activity are shown in Figure 6 separately for tropical cyclone and for earthquake and tsunami, while the contributions to the average annual loss from the different islands are displayed in absolute terms in Figure 7 and normalized by the total asset values in each island in Figure 8. Figure 8 shows how the relative risk varies by island across the country.

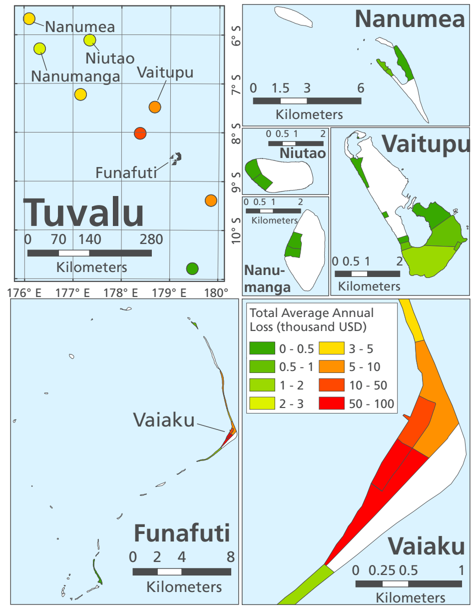


Figure 7: Contribution from the different islands to the average annual loss for tropical cyclone and earthquake (ground shaking and tsunami).

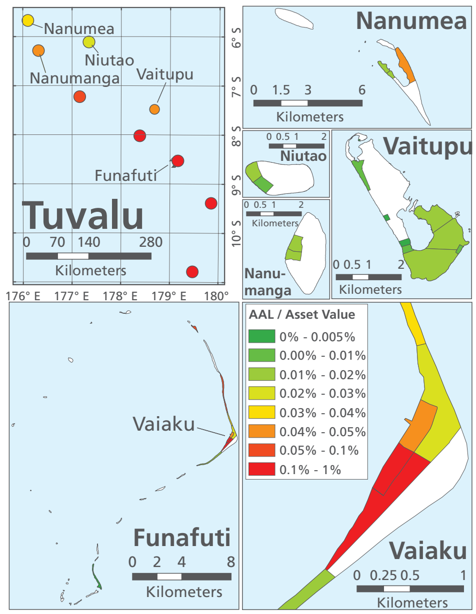


Figure 8: Contribution from the different islands to the tropical cyclone and earthquake (ground shaking and tsunami) average annual loss divided by the replacement cost of the assets in each island.

The same risk assessment carried out for Tuvalu was also performed for the 14 other Pacific Island Countries. The values of the average annual loss of Tuvalu and of the other 14 countries are compared in Figure 9.

In addition to estimating average risk per calendar year, another way of assessing risk is to examine large and rather infrequent, but possible, future tropical cyclone and earthquake losses. Table 2 summarizes the risk profile for Tuvalu in terms of both direct losses and emergency losses. The

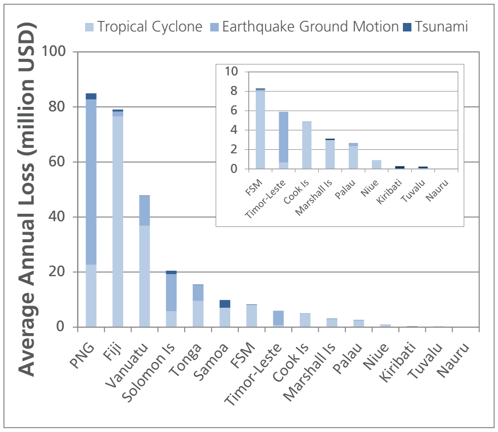


Figure 9: Average annual loss for all the 15 Pacific Island Countries considered in this study.

former are the expenditures needed to repair or replace the damaged assets while the latter are the expenditures that the Tuvaluan 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. The emergency losses are estimated as a percentage of the direct losses.

Table 2 includes the losses that are expected to be exceeded, on average, once every 50, 100, and 250 years. For example, a ***tropical cyclone loss exceeding 1.4 million USD, which is equivalent to about 4% of Tuvalu's GDP, is to be expected, on average, once every 100 years.*** In Tuvalu, tropical cyclone and earthquake losses are comparable. Earthquake losses caused by tsunamis are more frequent and severe than losses due to earthquake ground shaking.

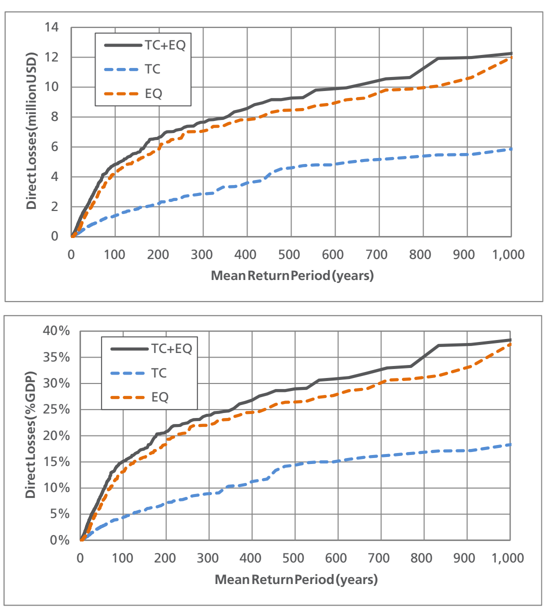


Figure 10: Direct losses caused by either tropical storms or earthquakes that are expected to be equaled or exceeded, on average, once in the time period indicated. Losses represented in absolute terms and normalized by GDP.

A more complete picture of the risk can be found in Figure 10, which shows the mean return period of direct losses in million USD generated by earthquake, tsunami and tropical cyclones combined. The 50-, 100-, and 250-year mean return period losses in Table 2 can also be determined from the curves in this figure. The direct losses are expressed both in absolute terms and as a percent of the national GDP.

In addition to causing damage and losses to the built environment and crops, future earthquakes and tropical cyclones 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, our model estimates, for example, that there is a ***40% chance in the next fifty years (100-year mean return period) that one or more events in a calendar year will cause casualties exceeding 20 people in Tuvalu***. Events causing 50 or more casualties are also possible but have much lower likelihood of occurring.

TABLE 2: Estimated Losses and Casualties Caused by Natural Perils

Mean Return Period (years)	AAL	50	100	250
Risk Profile: Tropical Cyclone				
Direct Losses				
(Million USD)	0.1	0.8	1.4	2.6
(% GDP)	0.2%	2.7%	4.4%	8.1%
Emergency Losses				
(Million USD)	0.0	0.2	0.3	0.6
(% of total government expenditures)	0.0%	0.5%	0.7%	1.4%
Casualties	1	10	16	29
Risk Profile: Earthquake and Tsunami				
Direct Losses				
(Million USD)	0.2	2.2	4.2	6.6
(% GDP)	0.5%	7.0%	13.1%	20.6%
Emergency Losses				
(Million USD)	0.0	0.5	1.0	1.5
(% of total government expenditures)	0.1%	1.2%	2.3%	3.5%
Casualties	0	0	4	17
Risk Profile: Tropical Cyclone, Earthquake, and Tsunami				
Direct Losses				
(Million USD)	0.2	2.8	4.8	7.2
(% GDP)	0.8%	8.9%	15.1%	22.5%
Emergency Losses				
(Million USD)	0.1	0.7	1.1	1.7
(% of total government expenditures)	0.1%	1.5%	2.6%	3.9%
Casualties	1	13	20	32

[1]Casualties include fatalities and injuries.

APPLICATIONS

The country risk profiles 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 profiles can inform the development of ***disaster risk financing and insurance solutions*** and ***ex ante budget planning*** options to increase the financial resilience of the countries against natural disasters while maintaining their fiscal balance. The earthquake and tropical cyclone hazard models also provide critical information for building codes in terms of country-specific seismic and wind loads that buildings should 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 database also provides extremely useful baseline data and information for conducting timely and effective ***post-disaster damage assessments***.

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