DISASTER RISK PROFILE

Comoros

Earthquake Flood Tropical Cyclone

Southwest Indian Ocean Risk Assessment and Financing Initiative

Building Disaster Resilience in Sub-Saharan Africa

WORLD BANK GROUP

GFDRR
Global Facility for Disaster Reduction and Recovery

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Africa Disaster Risk Profiles are co-financed by the EU-funded ACP-EU Natural Disaster Risk Reduction Program and the ACP-EU Africa Disaster Risk Financing Program, managed by the Global Facility for Disaster Reduction and Recovery.

The SWIO RAFI Project

The Southwest Indian Ocean Risk Assessment and Financing Initiative (SWIO RAFI) seeks to provide a solid basis for the future implementation of disaster risk financing through the improved understanding of disaster risks to participating island nations. This initiative is in partnership with the Ministries of Finance, National Disaster Risk Management Offices and Insurance sector representatives from The Comoros, Madagascar, Mauritius, Seychelles, and Zanzibar, and carried out in coordination with the Indian Ocean Commission (IOC) ISLANDS Project, the United Nations Office for Disaster Risk Reduction (UNISDR), and the French Development Agency (AFD). The SWIO RAFI supports the ISLANDS project's Islands Financial Protection Program (IFPP), which is also supported by the European Union (EU), UNISDR, and AFD. Africa Disaster Risk Profiles are co-financed by the EU-funded ACP-EU Natural Disaster Risk Reduction Program and the ACP-EU Africa Disaster Risk Financing Program, managed by the Global Facility for Disaster Reduction and Recovery.

SWIO RAFI complemented the ongoing work of the IOC to reduce vulnerability to natural disasters in accordance with the Mauritius Strategy for the Further Implementation of the Program of Action for the Sustainable Development of Small Island Developing States (SIDS) 2005–2015. More broadly, this initiative offers support to long-term, core economic, and social development objectives.

The risk modeling undertaken through SWIO RAFI focused on three perils: tropical cyclones, floods produced by events other than tropical cyclones, and earthquakes. Three hazards associated with tropical cyclones, wind, flooding and storm surge were considered in the risk assessment. In addition, as part of the earthquake risk assessment, tsunami risk zones were identified for each country.

The SWIO RAFI included the collection of existing hazard and exposure data, and the creation of new hazard and exposure data, that were used in the development of a risk assessment and risk profiles for The Comoros, Madagascar, Mauritius, Seychelles, and Zanzibar.

The exposure data includes detailed information on building construction for a variety of occupancy classes including: residential; commercial; industrial; public facilities such as educational facilities and emergency facilities; and infrastructure such as roads, airports, ports, and utilities. Finally, risk information that is determined through a combination of data on hazard, exposure, and vulnerability is provided at the national level and at several administration levels for each peril and for all perils combined, and broken down into occupancy classes.

In addition to the information provided in the risk profiles, the hazard and exposure data and the results of the risk analysis will be collated and stored on open data geospatial risk information platforms, or GeoNodes, in each country and will be available to a wide range of end-users. The results will be available in the form of geospatial files, text files, and detailed final reports and can be used for sector specific development planning and implementation.

COMOROS

Earthquake Flood Tropical Cyclone

This analysis suggests that, on average, Comoros experiences nearly **US$5.7 million** in combined direct losses from earthquakes, floods, and tropical cyclones each year. However, a specific event such as a **severe tropical cyclone** can produce **significantly larger losses**. For example, results suggest that a 100-year return period tropical cyclone event could produce direct losses of $43 million and require approximately $9.9 million in emergency costs.

Tropical cyclones are by far the **most significant risk** of the three perils in this study, causing approximately **64 percent** of the average **loss** per year. Flooding is the next largest risk, accounting for nearly 35 percent. It is important to note that an important risk on Grande Comore, the Karthala volcano, was not included in this analysis.

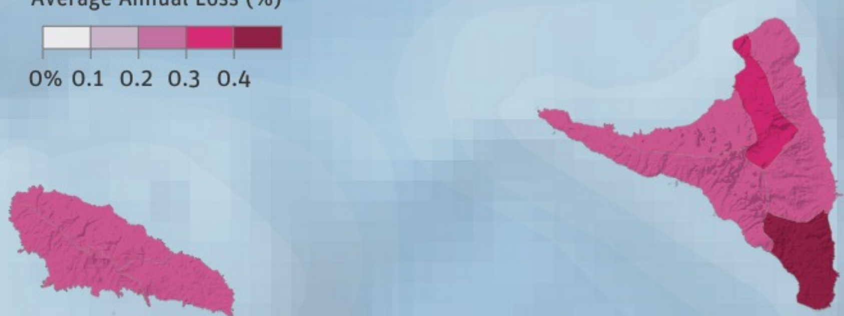
In this analysis the **residential sector** experiences **80 percent** of the combined losses, the public sector over 11 percent, and the commercial sector nearly 6 percent. The **highest loss** takes place in **Anjouan**, which experiences nearly 80 percent of the average annual losses from the three perils combined. In addition to the direct losses, an annual average of nearly **$1.3 million** is estimated for **emergency costs**.

Key Facts

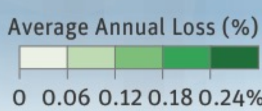
This analysis suggests that:

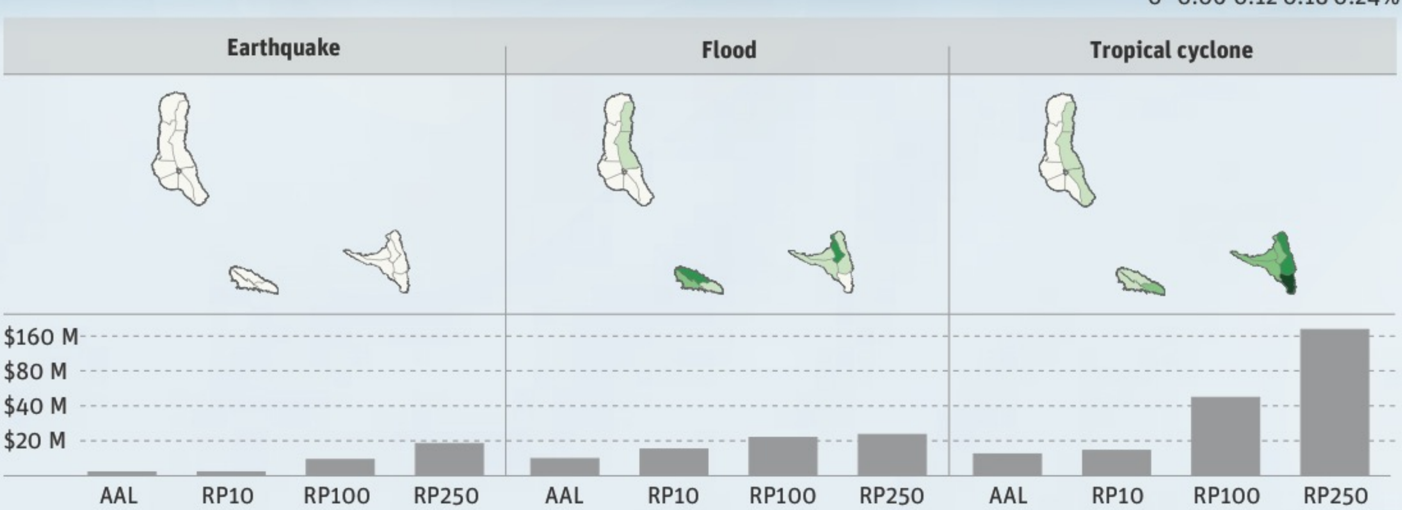
- The average annual direct losses from earthquakes, floods, and tropical cyclones are $5.7 million.
- The 100-year return period loss from all perils is over $48 million, or nearly 8% of Comoros's 2014 GDP.
- The 250-year return period loss from all perils could be $150 million, or 24% of Comoros's 2014 GDP.

Direct Losses from All Perils



Direct Losses by Hazard





COMOROS

GDP $620 million

Population 790,000

The **population** of Comoros in 2015 was approximately **790,000**. The most populous island is Grande Comore. Nearly 58 percent of Comoros's population lives in metropolitan or urban areas (that is, areas with more than 2,000 people per square kilometer) and slightly more than 29 percent in rural areas (fewer than 1,600 people per square kilometer). In 2014, Comoros's **gross domestic product** (GDP) was approximately **$620 million** ($1.3 billion in purchasing power parity), and the per capita GDP was $790.

For 2015, the estimated **total replacement value** for all residential, commercial, industrial, and public buildings and other infrastructure is estimated to be nearly **$2.6 billion**. The **largest concentration** of replacement value is on **Grande Comore**.

To assess risk better, replacement values and loss are often categorized according to occupancy and construction types. In terms of occupancy type, the **residential sector** accounts for over **66 percen**t of the total **replacement value**.

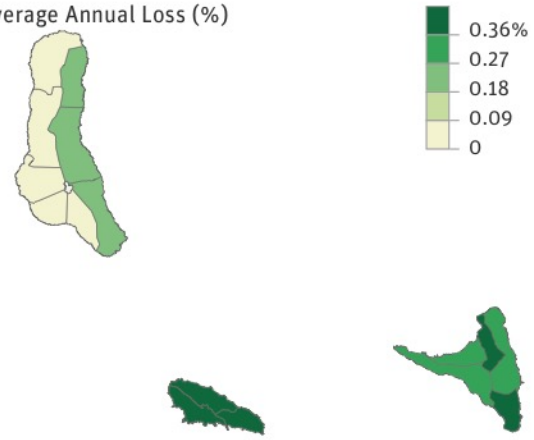
In terms of construction type, buildings with **masonry** and **concrete** wall **construction** account for nearly **83 percent** of the total **replacement value**.

Peril	Average Annual Loss		100-Year Return Period Loss	
	Total Direct Losses	Emergency Costs	Total Direct Losses	Emergency Costs
Earthquakes	$99,000	$16,000	$1.8 million	$280,000
Floods	$2.0 million	$460,000	$10 million	$2.3 million
Tropical Cyclones	$3.6 million	$830,000	$43 million	$9.9 million

Direct Losses by Building Type for all Hazards

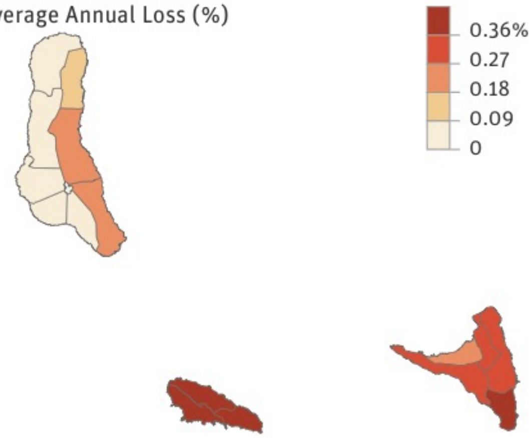
Residential

Average Annual Loss (%)



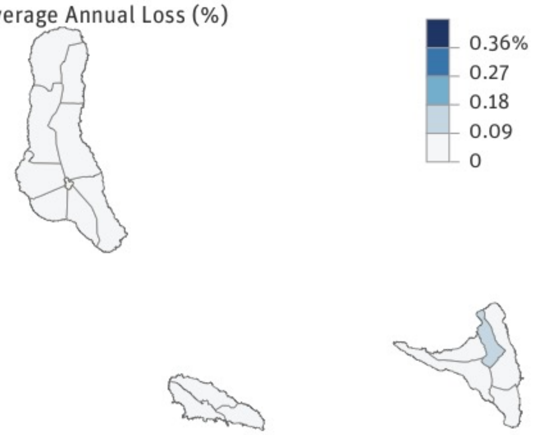
Commercial/Industrial

Average Annual Loss (%)



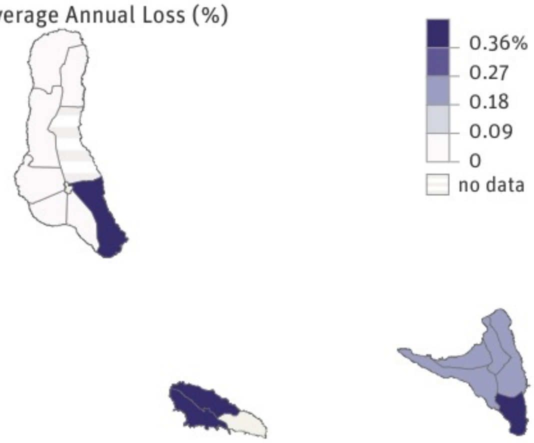
Infrastructure

Average Annual Loss (%)



Public*

Average Annual Loss (%)



*Education, Healthcare, Religion, Emergency

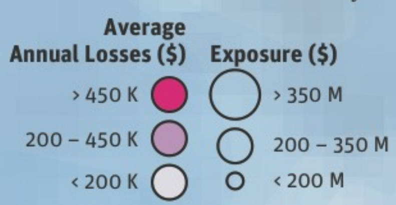
COMOROS

This analysis suggests that, on average, Comoros will experience around **$2.0 million** each year in direct losses from flooding, amounting to nearly **35 percent** of the country's total annual direct losses from earthquakes, floods, and tropical cyclones.

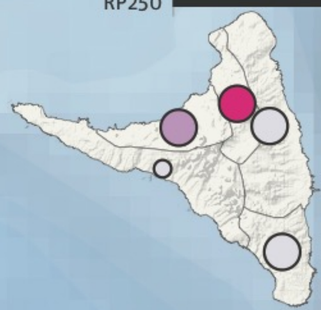
It is estimated that over **87 percent** of the direct losses from flooding are from the **residential sector** and 5 percent from the commercial sector. Losses to public assets and industry contribute approximately 6 percent and 1 percent, respectively, to the total. Annual **emergency costs** for floods are estimated at over **$460,000**, on average.

This analysis shows that **Anjouan** is at **greatest risk** for flood loss, with an average loss per year of **$1.3 million** from nontropical cyclone flooding nearly 66 percent of the total flood loss. On Anjouan, Ouani has the highest risk of direct losses with average annual flood losses of $660,000. Flood risk on Grande Comore and Moheli are similar with average annual flood losses of $350,000 and $330,000, respectively, despite the large difference in assets at risk ($1.3 billion in Grande Comore and $170 million in Moheli).

Significant flood losses can **occur frequently**. For Comoros as a whole, direct losses from a 10-year flood event are estimated to be $4.8 million, and direct losses from a 100-year flood event are estimated to be $10 million.



Return Period	Total Modeled Losses
AAL	$2 million
RP10	$5 million
RP100	$10 million
RP250	$12 million



Modeled Direct Losses

		Average Annual Loss
Residential	AAL	$1.5 million
	RP10	$4 million
	RP100	$8.5 million
	RP250	$9.5 million
Commercial/ Industrial	AAL	$90,000
	RP10	$250,000
	RP100	$500,000
	RP250	$600,000
Public	AAL	$100,000
	RP10	$300,000
	RP100	$800,000
	RP250	$950,000
Infrastructure	AAL	$20,000
	RP10	$50,000
	RP100	$150,000
	RP250	$200,000

Key Facts

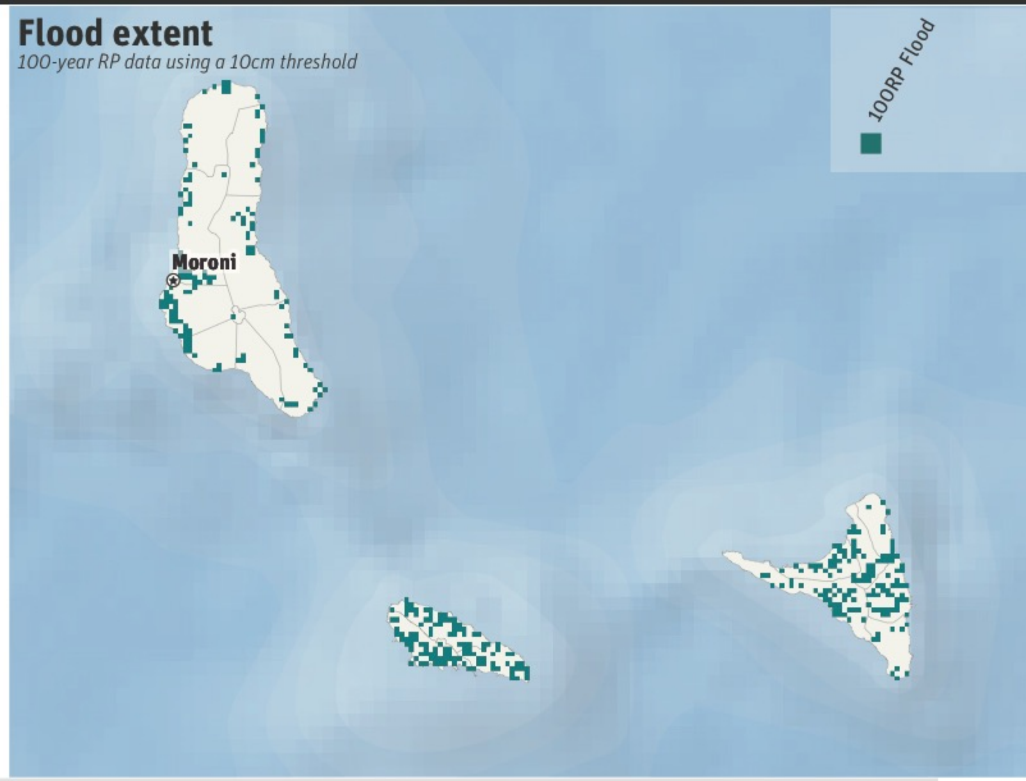
This analysis suggests that:

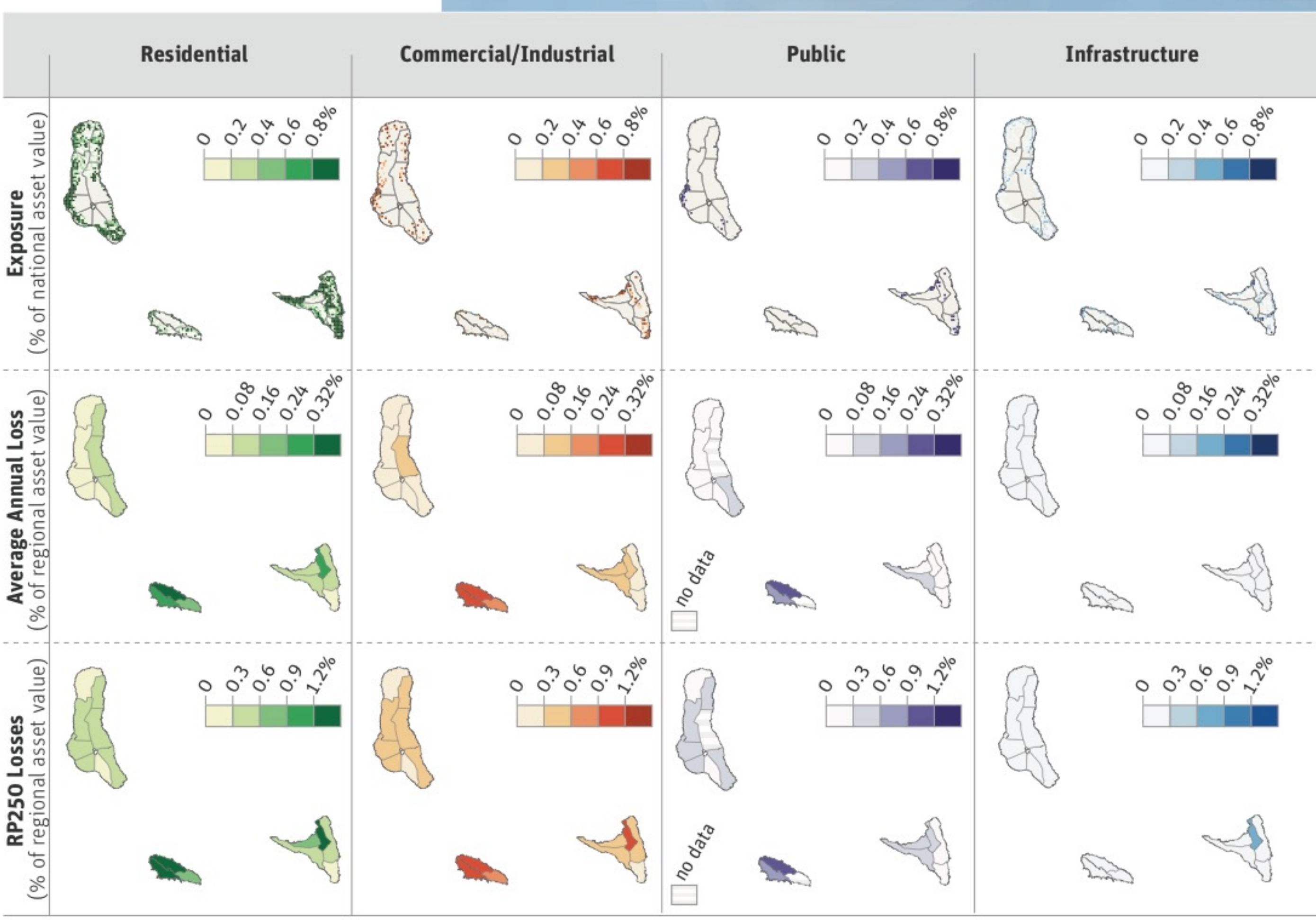
- The average annual direct loss from flooding is $2.0 million.
- Anjouan has the greatest risk of direct loss from flooding with an average annual loss of $1.3 million.
- The 100-year direct loss to Comoros from flooding is $10 million.

FLOOD
COMOROS

In this analysis, the modeled annual average rainfall from non-tropical cyclone events is 979 mm with a minimum of 446 mm and a maximum of 1,757 mm.

Flood depths are highest in Anjouan and Moheli and Grande Comore. Modeled flood depths can exceed 1 m for the Fomboni region in Moheli and the for the Ouani region on Anjouan.





TROPICAL CYCLONE

COMOROS

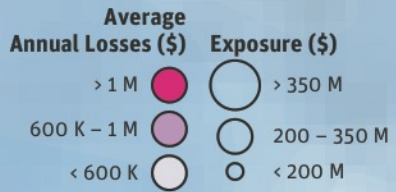
Tropical cyclones are common in the Southwest Indian Ocean region, and Comoros occasionally experiences **a tropical cyclone landfall.** The wind, rain, and storm surge associated with tropical cyclones all contribute to losses.

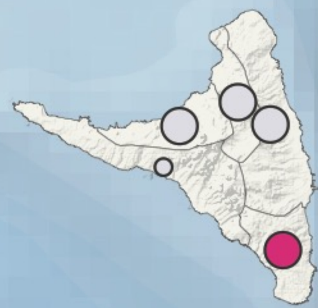
A recent example of a tropical cyclone affecting Comoros is **Hellen**, which passed to the south in March **2014**. The cyclone caused **one fatality** due to storm surge, **damaged over 900 houses**, and caused flooding and landslides, particularly on Moheli and Anjouan.[1]

This analysis suggests that, on average, Comoros will experience around **$3.6 million** in **direct losses annually** from winds, flooding, and storm surge associated with tropical cyclones. This is **64 percent** of the country's total annual direct losses from earthquakes, floods, and tropical cyclones. The results suggest that almost **77 percent** of the loss from tropical cyclones originates from the **residential sector** and nearly 6 percent from the commercial sector. Losses to the public sector and industry contribute approximately 13 percent and 1 percent, respectively, to the total of direct losses. Annual **emergency costs** for tropical cyclones are estimated at nearly **$830,000**, on average.

Tropical cyclones generate wind, flood, and storm surge hazards. On average in this analysis, **winds** cause over **54 percent** of the **loss** from the three hazards, while storm surge causes around 43 percent and flooding around 2 percent of the remaining damage.

Return Period	Total Modeled Losses
AAL	$4 million
RP10	$5 million
RP100	$40 million
RP250	$150 million





Modeled Direct Losses

		Average Annual Loss
Residential	AAL	$2.5 million
	RP10	$3.5 million
	RP100	$35 million
	RP250	$100 million
Commercial/ Industrial	AAL	$250,000
	RP10	$300,000
	RP100	$3 million
	RP250	$9.5 million
Public	AAL	$500,000
	RP10	$600,000
	RP100	$5.5 million
	RP250	$20 million
Infrastructure	AAL	$70,000
	RP10	$20,000
	RP100	$550,000
	RP250	$3.5 million

Key Facts

This analysis suggests that:

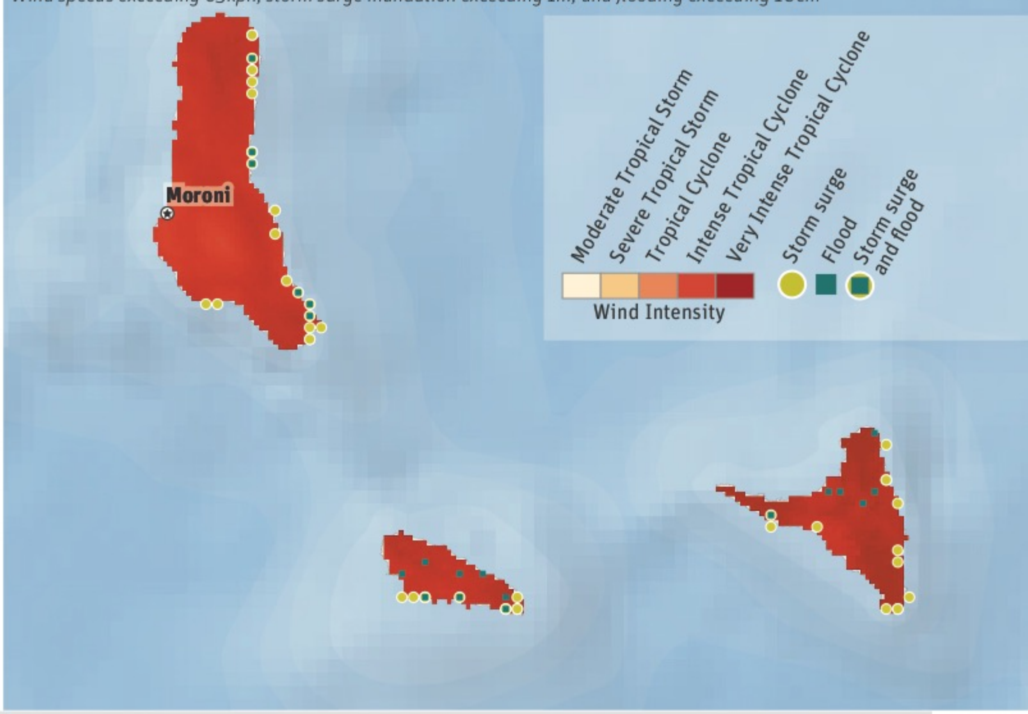
- The average annual direct loss from tropical cyclones is $3.6 million.
- Anjouan has the greatest risk of direct loss from tropical cyclones with an average annual loss of $3.1 million.
- The 100-year direct loss to Comoros from tropical cyclones is $43 million.

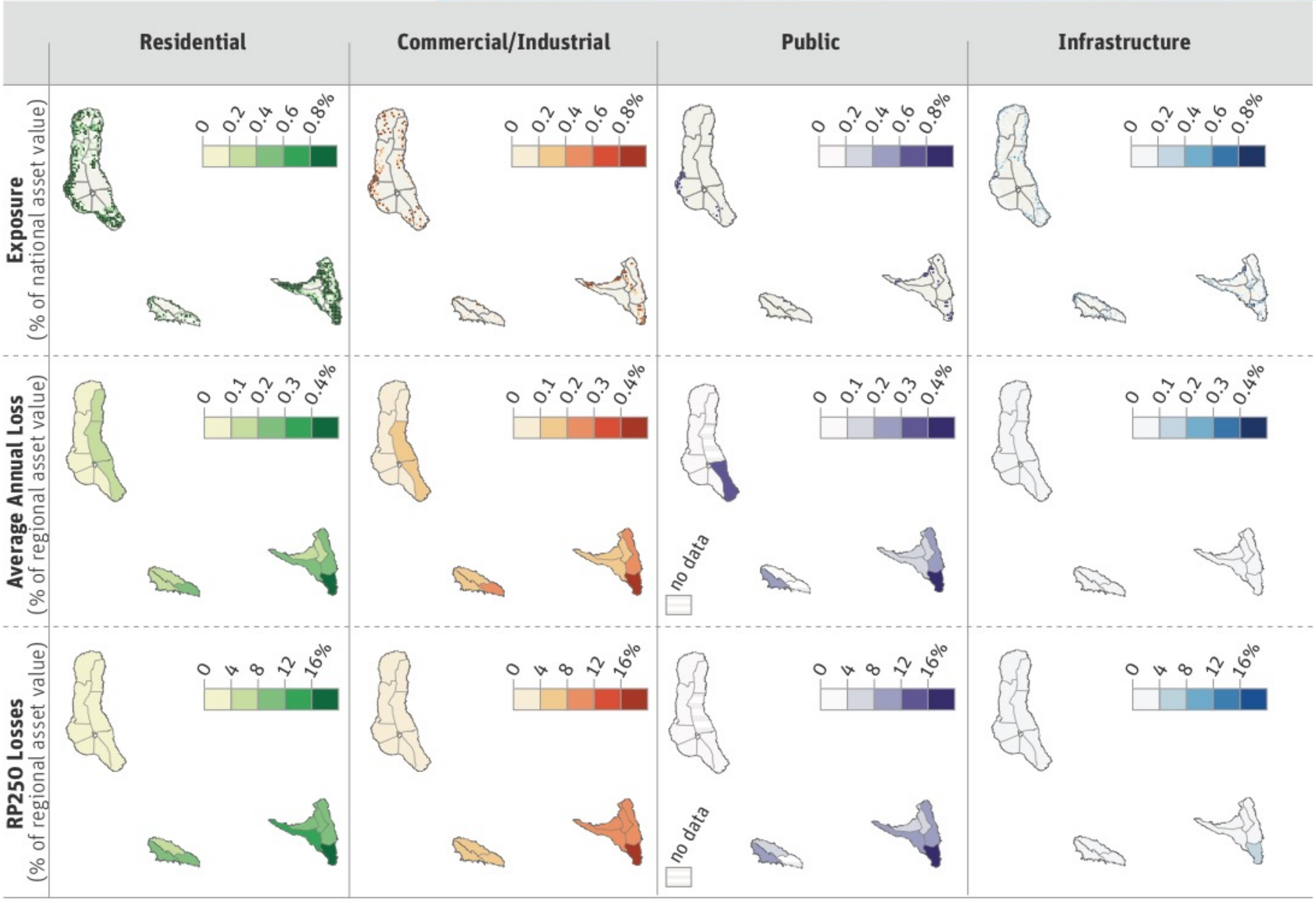
Three hazards are produced by tropical cyclones: wind, storm surge, and flooding produced by excessive rainfall. For Comoros, this analysis suggests that the greatest **wind** hazard occurs on the **northeast** and **southeast** ends of **Anjouan**. Winds associated with the 100-year tropical cyclone can exceed 200 kph.

This analysis suggests that the greatest flood hazard associated with tropical cyclones occurs on **Anjouan** and **Moheli**. Storm surge hazard is greatest along the southern and eastern coasts of Comoros. In places **storm surge** can exceed **1.5 meters**.

Tropical cyclone hazards

Wind speeds exceeding 63kph, storm surge inundation exceeding 1m, and flooding exceeding 10cm





COMOROS

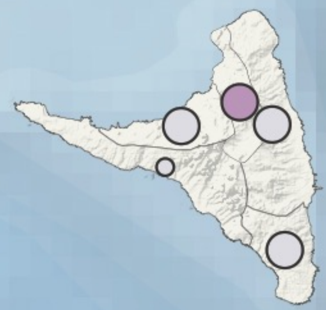
Earthquakes are common in the Southwest Indian Ocean region, and Comoros is somewhat seismically active compared to other islands in the region. However, **damage** from earthquakes is **not common**. The two major sources of seismic activity are the Mid-Indian Ridge in the Indian Ocean and the East-African Rift system. Earthquakes in these regions are frequent but usually of low to moderate magnitude. A **magnitude 5.1 event** occurred 88 kilometers south of Moroni on **September 29, 2016**.

This analysis suggests earthquakes account for around **2 percent** of Comoros's **total annual direct losses** from earthquakes, floods, and tropical cyclones, amounting to an estimated $99,000 on average each year.

The results suggest that the region with the **greatest absolute risk** of loss from earthquakes is **Grande Comore,** with an expected loss per year of $55,000, nearly 70 percent of the total direct loss from earthquakes. Over **75 percent** of the loss from earthquakes is from the **residential sector**, around 13 percent from the public asset sector, and around 6 percent from the commercial sector. Annual **emergency costs** for earthquakes are estimated at **$16,000**, on average.

Significant losses from earthquakes are expected to **occur relatively infrequently**. For example, this analysis suggests that direct losses for earthquakes with a 50-year return period are ~$55,000 and with a 100-year return period are $1.8 million.

Return Period	Total Modeled Losses
AAL	$100,000
RP10	$0
RP100	$2 million
RP250	$7 million



Modeled Direct Losses

		Average Annual Loss
Residential	AAL	$75,000
	RP10	$0
	RP100	$1.5 million
	RP250	$5 million
Commercial/ Industrial	AAL	$6,000
	RP10	$0
	RP100	$90,000
	RP250	$400,000
Public	AAL	$15,000
	RP10	$0
	RP100	$60,000
	RP250	$800,000
Infrastructure	AAL	$4,000
	RP10	$0
	RP100	$2,000
	RP250	$200,000

Key Facts

This analysis suggests that:

- The average annual direct loss from earthquakes is $99,000.
- Grande Comore has the greatest risk of direct loss from earthquake with an average annual loss of $55,000.
- The 100-year direct loss to Comoros from earthquakes is $1.8 million.

EARTHQUAKE
COMOROS

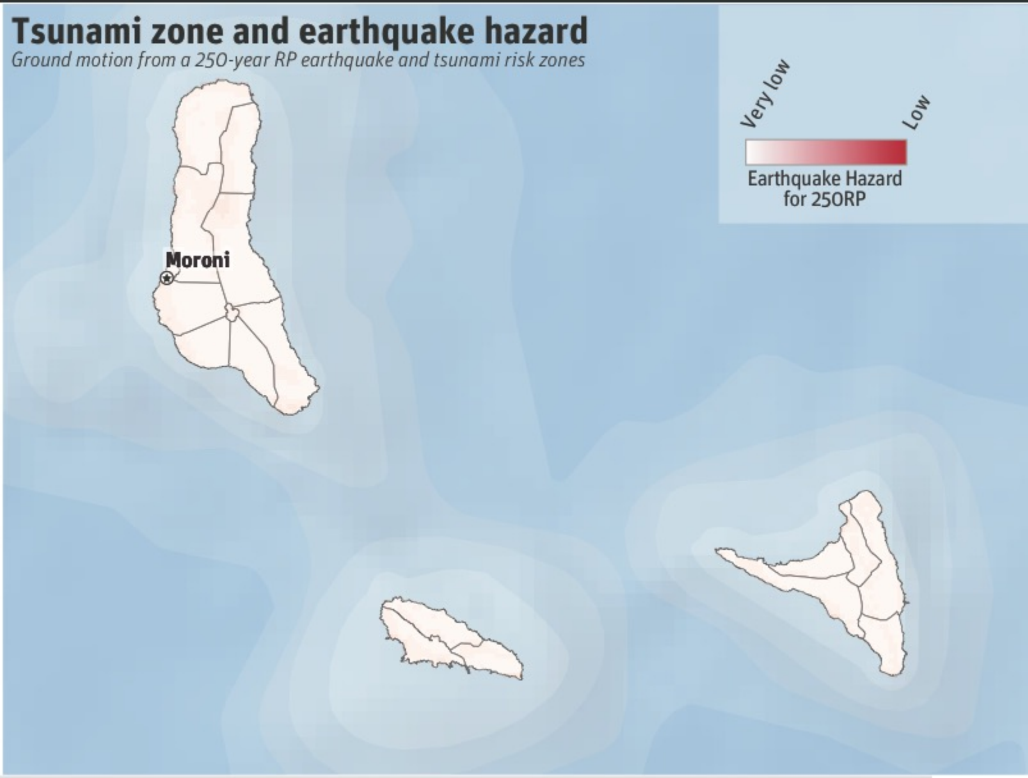
This analysis suggests that the ground motion hazard from **earthquakes is low** throughout Comoros. Earthquakes that would cause significant damage to structures have only a small probability of occurrence.

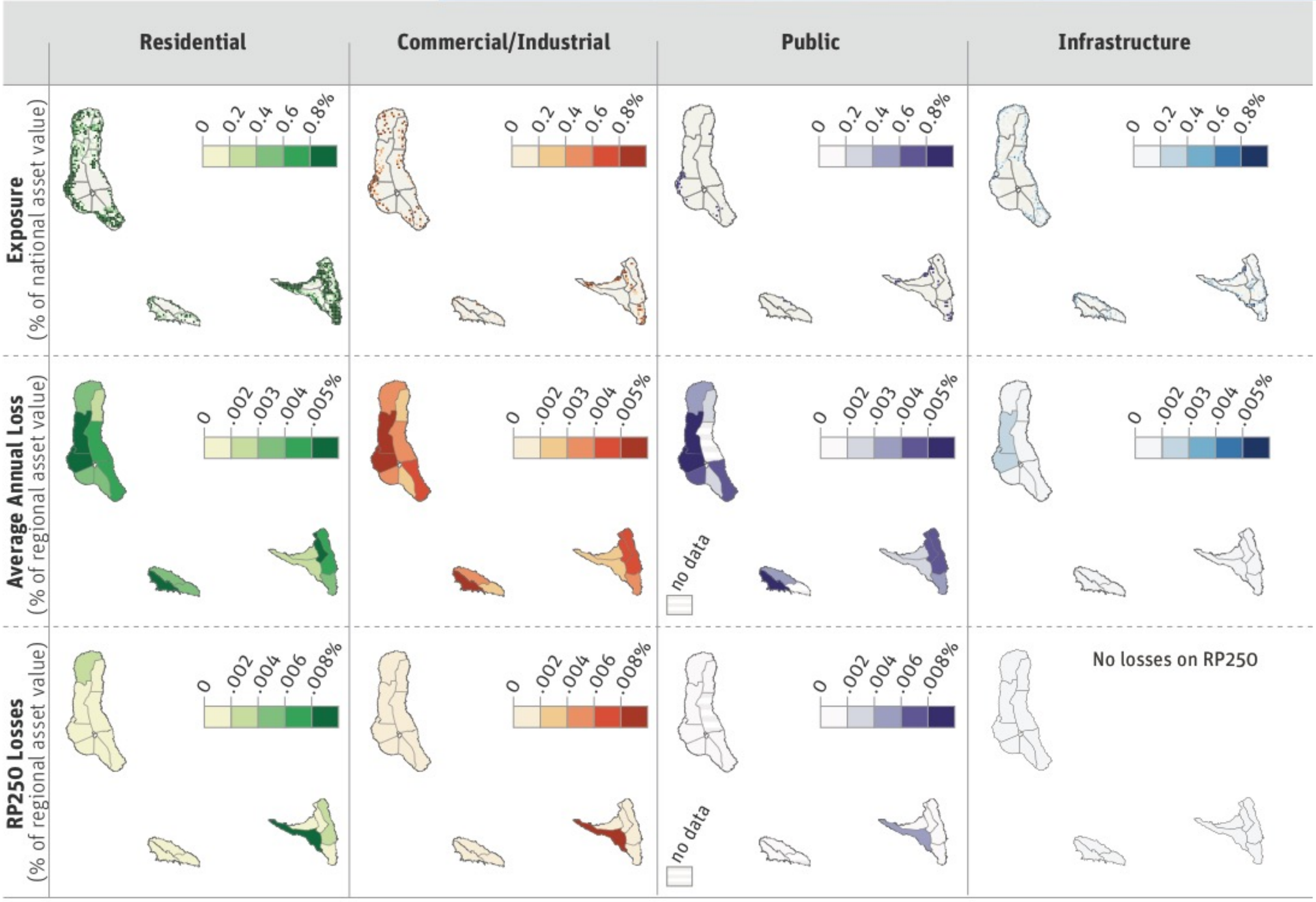
Tsunamis usually result from high-magnitude, subduction-zone earthquakes. The Southwest Indian Ocean region does not experience many high-magnitude earthquakes, nor does it contain major subduction zones. The entire region is at risk, however, of tsunamis generated by subduction zones elsewhere in the Indian Ocean.

A recent tsunami event that affected the Southwest Indian Ocean region was the **2004 Indian Ocean tsunami**. Some locations along the northeastern tip of Grande Comore experienced inundation of **6.8 meters above sea level**.

Tsunami zone and earthquake hazard

Ground motion from a 250-year RP earthquake and tsunami risk zones





DISASTER RISK PROFILES

METHODOLOGY

Risk

These risk profiles have been developed from a multi-hazard risk assessment using a variety of exposure data and vulnerability functions. Modeled perils include earthquake, flood, and tropical cyclone. The results for individual and aggregated perils are available in several formats, including geospatial data and text files. The risk profile results are presented in terms of average loss per year and for selected return periods. For details on the development of the risk profiles, see the final report "Southwest Indian Ocean Risk Assessment Financing Initiative (SWIO RAFI): Component 4 – Risk Profiles". Brief explanations of the exposure and hazard data and the vulnerability functions are given below.

Hazard

This study encompasses four perils: earthquake, flood, landslide, and tropical cyclone. One or more hazards are associated with each peril. For example, the hazards associated with tropical cyclones include strong winds, storm surge, and flooding. For perils other than landslide, a catalog representing 10,000 years of simulated events was constructed using empirical and theoretical principles and information derived from historical observations. A variety of statistical characteristics derived from the events in the catalogs are consistent with the historical record for each peril. The catalog (which is proprietary) includes information such as the intensity—for example, central pressure for a tropical cyclone and moment magnitude for an earthquake—and location of each peril event. This information is then coupled with peril-specific empirical and theoretical considerations to describe the spatial distribution of hazard intensity for each simulated peril event in the catalog, at a grid spacing of about one kilometer. The information is used to determine the hazard intensities expected at each return period.

EARTHQUAKE

This analysis suggests that there is a low likelihood of earthquakes in the SWIO region. The catalog of synthetic earthquake events is developed using characteristics based on the historical record of 1,228 earthquakes with moment magnitudes 5.0 or greater that occurred in the SWIO basin between 1901 and 2014 and the slip rates and geometries of known faults in the region. Ground motion prediction equations are used to determine the spatial distribution of ground motion (such as peak ground acceleration, or PGA) produced by each earthquake event.

FLOOD

The risk assessment indicates that floods from rainfall not associated with tropical cyclones are a significant hazard in the SWIO region, particularly for the areas closer to the equator. Flood hazard statistics in this analysis are ultimately based on satellite-derived rainfall estimates from the years 1998–2013. The satellite-derived data are used with a rainfall model to develop a catalog of daily rainfall produced by events other than tropical cyclones. A flood model then dynamically distributes the rainfall throughout the affected region and calculates flood depths.

TROPICAL CYCLONE

This analysis suggest that the most costly catastrophic hazard in the SWIO basin is tropical cyclone. The historical record of tropical cyclones in the region includes 847 events that took place between the 1950 and 2014. The event catalog is developed using characteristics of the historical catalog, such as annual tropical cyclone frequency, landfall frequency, seasonality, genesis location, forward speed, central pressure, and radius of maximum winds. Three tropical cyclone hazards are considered: wind, flooding from rainfall, and storm surge.

Tropical cyclone wind speeds are calculated using an equation that includes parameters such as the difference between the tropical cyclone's central pressure and the surrounding environment, a storm's forward motion and its asymmetry, and account for surface features such as land use.

Rainfall produced by modeled tropical cyclones is calibrated using satellite-derived rainfall estimates and used as a boundary condition to force a flood model that accounts for factors such as hourly rainfall, elevation, and soils.

Storm surge is derived from a variety of tropical cyclone characteristics that include central pressure, forward motion of the storm, maximum wind speed, and radius of maximum winds. For a tropical cyclone in the Southern Hemisphere, the highest storm surge generally occurs near the radius of maximum winds on the left side of the storm track.

Exposure

The methodology used to develop the exposure data is illustrated in figure A1. The exact process varies by country because of differences in available data. The exposure database for each island nation is constructed from various data sources, including government censuses, local agencies, satellite imagery, publicly available spatial statistics, and previous regional investigations. The end result is datasets that represent the built environment of each island nation and include nationally appropriate replacement values (that is, the estimated cost to rebuild a structure as new), construction characteristics, and occupancy classes.

The exposure data are divided into eighteen different occupancy classes spanning different types of residential, commercial, industrial, public facility, and infrastructure assets. The residential occupancy class includes single and multifamily residences. The commercial class includes general commercial buildings and accommodation. The exposure groups in the public occupancy class are health care services, religion, emergency services, primary educational, university educational, and general public facilities. The infrastructure occupancy classes are road/highway, bus/rail, airport, maritime port, electrical utility, and water utility. An "unknown" occupancy class is also assigned.

In addition to their categorization by occupancy class, the exposure data are categorized according to thirteen construction classes. Seven of these are specific to infrastructure occupancies and include structures such as roads, railroads, and bridges. Five represent common construction classes, such as single-story traditional bamboo and earthen buildings and single and multistory traditional wood, wood frame, masonry/concrete, and steel frame buildings. As with occupancy class, an "unknown" construction class is assigned.

The exposure data for residential, commercial, and general industrial assets are provided on a grid of 30 arc-seconds (approximately one kilometer). When high-resolution government and infrastructure data are available, these assets are captured at their individual exposure locations. When location-level information is not available, government and infrastructure assets are distributed to the one-kilometer grid.

Vulnerability

Vulnerability functions appropriate to the construction and occupancy classes most commonly found in the SWIO region are used to estimate loss from a hazard. The functions calculate the average level of damage to the structures using the hazard intensity and information on their occupancy and construction. The damage level represents the fraction of the total building replacement value that has been damaged. Vulnerability functions used in this study have been developed specifically for the SWIO region based on research on local building practices, applicable building codes, engineering analysis, historical damage reports, and expert judgment.

Vulnerability functions for earthquake ground shaking, non-tropical cyclone flooding, tropical cyclone flooding, and tropical cyclone storm surge are assumed to be uniform throughout the SWIO region for all occupancies other than infrastructure. Except for infrastructure, the tropical cyclone wind damage functions for Mauritius and Seychelles are modified to be less vulnerable than the SWIO base functions used for the other island nations because of their history of more stringent construction practices relative to the other three nations. All damage functions for infrastructure occupancy classes are assumed to be uniform for all perils throughout the SWIO region.

** All dollar amounts are U.S. dollars unless otherwise indicated.*

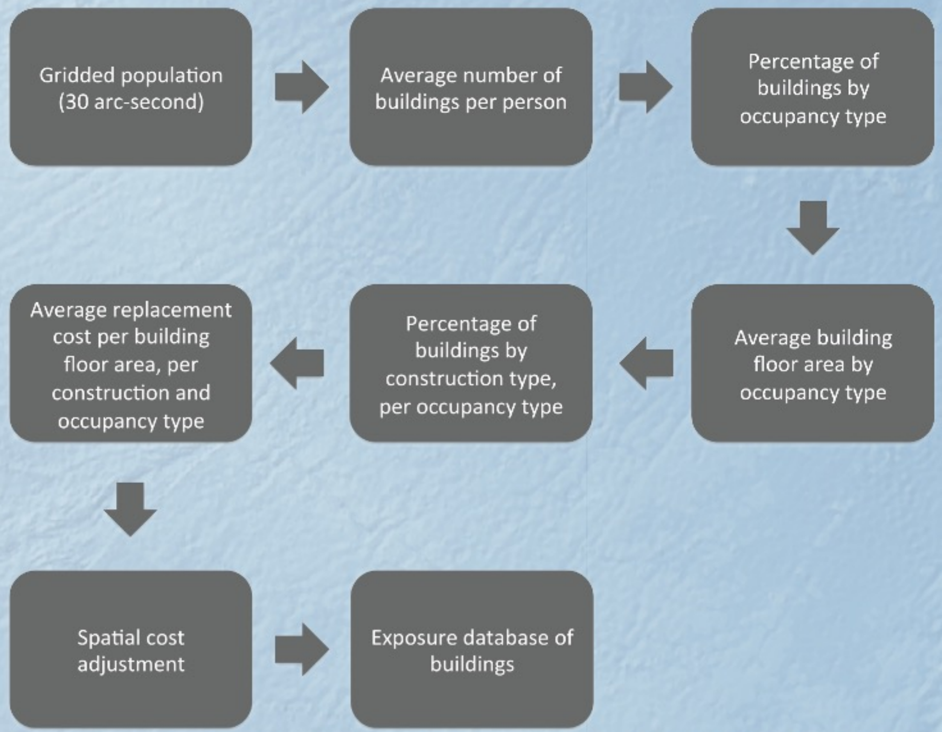


Figure A1. Schematic diagram illustrating the methodology used to develop the SWIO-RAFI exposure data

GLOSSARY

Average Annual Loss

The modeled average annual loss (AAL) is equal to the total of all impacts produced by a hazard (e.g. earthquake) in a specified time period (e.g. 10,000 years) divided by the number of years in that specified time period (e.g. 10,000 years).

Building Construction Class

Building Construction Class is used to classify an asset's construction, which determines an asset's vulnerability to a certain hazard, contributing to a risk estimate. For example, a traditional wood building is more vulnerable (i.e. likely to be damaged or destroyed) by a tropical cyclone than a building made of steel-reinforced concrete. Thus an area with traditional wood buildings is likely to experience more damage and larger losses from a tropical cyclone than an area with steel-reinforced concrete buildings. Building Construction Class is one of the factors used to determine vulnerability (see below).

Building Type

Building Type, or Occupancy Class, specifies the usage of a given building, which contributes to a building's vulnerability. The building types used in these profiles are: residential, commercial, industrial, infrastructure, and public.

Each building type has subtypes:

- Residential: single, multi-family (e.g. apartment)
- Commercial: accommodation (e.g. hotel), commercial (e.g. shop)
- Industrial: general industrial (e.g. factory)
- Infrastructure: bus terminals, rail terminals, airports, maritime ports, utilities, roads, highways
- Public: healthcare, education, religious, emergency services, general public facilities

Building Type is one of the factors used to determine vulnerability (see below).

Exposure / Exposed Assets

Exposure refers to assets such as buildings, critical facilities and transportation networks, which could be damaged by a hazard. A variety of attributes associated with the exposure, such as location and occupancy and structural characteristics, help determine the vulnerability of the exposure to a hazard.

Hazard

Hazard refers to the damaging forces produced by a peril, such as inundation associated with flooding, or winds produced by a tropical cyclone. A single peril can have multiple hazards associated with it. Those associated with a tropical cyclone, for example, include strong winds, storm surge and flooding.

Impact

Impact refers to the consequences of a hazard affecting the exposure, given the exposure's vulnerability. The impact on structures is usually quantified in terms of direct monetary loss.

Replacement Value

Replacement value refers to the estimated amount it would cost to replace physical assets.

Return Period (RP)

Throughout this profile 10-year (RP10), 100-year (RP100), and 250-year (RP250) events are referenced. These events have intensities that (on average) are expected to occur once during a "return period". A return period is based on the probability that an event could happen in a given year. The larger the return period for an event, the less likely its occurrence, and the greater its intensity. The probability of an event occurring in any given year equals 1 divided by the number of years named in the "X-year event", e.g. for a 10-year event (an event with a 10-year return period), the probability is 1/10 or 10%; for a 100-year event, the probability is 1/100 or 1%.

Risk

Risk is a combination of hazard, exposure, and vulnerability. It is quantified in probabilistic terms (for example, average annual loss) using the impacts of all events produced by models.

Vulnerability

Vulnerability accounts for the susceptibility of the exposure to the forces associated with a hazard. Vulnerability accounts for factors such as the materials used to build the asset (as specified by the Building Construction Class) and the asset's use (as specified by the Building Type).

NOTES

[1] UNOCHA, "Comoros Islands, Cyclone Hellen," http://reliefweb.int/sites/reliefweb.int/files/resources/Comoros_Hellen%20Impact_02%20April%202014_OCHA%20ROSA.pdf

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