GRMA Country Insight Series

Global Risk Modelling Alliance

CLIMATE AND DISASTER RISK ASSESSMENT LANDSCAPE: COSTA RICA

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ACRONYMS

AAL	Average Annual Loss
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CDRFI	Climate and Disaster Risk Finance and Insurance
CDRI	Coalition for Disaster Resilient Infrastructure
CNE	Comisión Nacional de Emergencias (National Emergency Commission)
EM-DAT	Emergency Events Database
ENSO	El Niño Southern Oscillation
GAR	Global Assessment Report (on Disaster Risk Reduction)
GEM	Global Earthquake Model
GFDRR	Global Facility for Disaster Reduction and Recovery
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GRAF	Global Risk Assessment Framework
GRMA	Global Risk Modelling Alliance
IGN	Instituto Geográfico Nacional
IMN	Instituto Meteorológico Nacional
INFORM	Index for Risk Management
JRC	Joint Research Centre (European Commission)
NAP	National Adaptation Plan
OECD	Organisation for Economic Co-operation and Development
SUGESE	Superintendencia General de Seguros
UNDRR	United Nations Office for Disaster Risk Reduction
WB	World Bank

INTRODUCTION

The Climate and Disaster Risk Assessment Landscape Series by the Global Risk Modelling Alliance (GRMA) aims to provide a summary of available climate and disaster risk analysis and information in GRMA partner countries. Each publication summarises, for one country, the availability of global and local sources of data, models and risk estimates, climate change analysis and impacts, and highlights gaps in risk information at the time of writing.

The review of Costa Rica was conducted as part of the GRMA programme in Costa Rica. In 2023, the Ministry of Finance of Costa Rica requested for support from the GRMA, mandating Superintendencia de Seguros Costa Rica (SUGESE) as the focal point. The GRMA is providing EUR 1.6 million in support for climate risk analytics and capability development for the agriculture, tourism and infrastructure sectors. The programme's priorities were co-defined in partnership with SUGESE and Costa Rica's GRMA Technical Working Group.

In partnership with SUGESE and its cross-institution Technical Working Group and over the period of January 2025 to April 2026, the GRMA programme is providing models, data and capability development in the following areas:

- Multi-hazard analysis of critical infrastructure in one canton to demonstrate a framework for infrastructure risk assessment; to include fluvial, pluvial, coastal flood and earthquake risk
- Fluvial and pluvial flood and agricultural drought impacts on crops and livestock
- Climate risk to small and medium hotel businesses in the tourism sector; to include fluvial, pluvial, coastal flood and earthquake risk.
- Multi-hazard impacts on major road infrastructure; to include fluvial, pluvial and coastal flood, earthquake, volcanic hazards and landslide.

A more detailed description of GRMA's work with Costa Rica can be found in the project brief here.

This work was also included in the Global Shield Stocktake and Gap Analysis report[1], reaffirming the critical importance of climate risk analytics in laying the foundation for climate and disaster risk finance and management in a country. The GRMA is a key expert resource and partner initiative to the Global Shield.

[1] More information on the Global Shield against Climate Risks initiative and its in-country programme, including the full stocktake and gap analysis of the CDRFI landscape in Costa Rica, can be found on the respective country page here. This country brief may include supplemental information to the Global Shield Stocktake due to subsequent work undertaken in the GRMA programme.

ACKNOWLEDGEMENTS

This brief was authored by Dr. Stuart Fraser and Dr. Simon Wild (GRMA). It benefitted from concurrent research for a World Bank report on risk information of Costa Rica's infrastructure (not yet published). This review was further enriched by the review and guidance of the Global Shield secretariat country team. Finally, our thanks go to the Technical Working Group convened by Superintendencia de Seguros Costa Rica (SUGESE) for their insights. The TWG consists of: the Comisión Nacional de Prevención de Riesgos y Atención de Emergencias (CNE), Iniciativa Fu-Turismo, Sistema de Banca para el Desarrollo (SBD), Ministerio de Agricultura (MAG), Laboratorio Nacional de Materiales y Modelos Estructurales, Universidad de Costa Rica (Lanamme), Municipalidad de Heredia and Instituto Meteorológico Nacional de Costa Rica (IMN).

Published January 2026. Unless otherwise indicated, all data and analysis presented in this report are up-to-date as of October 2025.

COUNTRY CONTEXT

Costa Rica's climate is highly variable due to its diverse geography, which includes volcanic mountains and its location between the Pacific Ocean and the Caribbean Sea. The country experiences two main rainfall regimes. The Pacific Coast is characterized by a distinct dry season from November to April and a rainy season from May to October, while the Caribbean slope has a more consistently hot and humid climate with year-round rainfall and less pronounced seasonal variations. Further adding to this variability within one year, the El Niño Southern Oscillation (ENSO) phenomenon adds variability between different years. Occurrence of extreme weather events such as storms, floods, and droughts can also be related to ENSO cycles. El Niño years are typically associated with droughts on the Pacific coast, whereas La Niña years often result in heavier rainfall, especially affecting the Caribbean side.

Geophysical hazards, particularly earthquakes, also pose a significant threat to Costa Rica, with the subduction of the Cocos plate beneath the Caribbean plate generating frequent seismic activity. Costa Rica's volcanic risk is considerable, with the National Emergency Commission (CNE) identifying 16 peaks of known volcanic origin and 9 active volcanoes. The country's location within the Pacific "Ring of Fire" further amplifies its vulnerability to volcanic eruptions. Landslides can pose an additional risk and can be triggered by intense rainfall, earthquakes, or volcanic activity.

Risk indexes such as INFORM (JRC, 2024) and the World Risk Report (Bündnis Entwicklung Hilft / IFHV, 2024) provide a high-level view of risk relative to a country's peers, and some information on the general drivers of risk. INFORM ranks Costa Rica 99th, with 'medium' overall risk – with hazard exposure considered to be 'medium', vulnerability 'medium', and lack of coping capacity to be 'low'. Hazard specific risk is assessed ranging from 0 to 10 (10 being very high risk) with earthquake 9.1, tsunami 8.3, coastal flood 4.1, river flood 2.4, tropical cyclone 1.3, and drought 1.0. The World Risk Report ranks Costa Rica's risk overall 'high' with 'very high' exposure and 'low' vulnerability. A review of historical disaster data, available for the period 1910-2024 in the EM-DAT catalogue (EM-DAT) shows 77 recorded disaster events. For comparison only the events from 1968 onwards and excluding epidemics are considered. 43% were listed as flood, 19% earthquake, 16% storm, 9% volcanic activity, and 7% drought. Floods caused 36% of the total economic damages and 31% of the fatalities, storms contributed to 37% of the economic damages and claimed 24% of the fatalities, and earthquakes caused only 24% of the economic damages and 19% of the fatalities.

Table 1. EM DAT 1968-2024, excluding epidemics

Disaster type	Subtype	Event count	Total Deaths	Total Affected	Total Damage (US$)
Drought	Drought	5			45
Earthquake	Earthquake	13	127	164,493	633
Flood	Riverine	21	97	571,659	704
Flood	Undefined	9	54	396,264	270
Landslide	Landslide	1	7	200	
Storm	Tropical Cyclone	10	114	1,094,836	987
Storm	Undefined	1	3	216,000	
Volcano	Ash Fall	6	89	104,571	44
Wildfire	Forest Fire	2		1,200	

The DesInventar database provides historical event data from 1968-2019. In the over 18,000 data entries (including a wide range of events such as drowning and explosions) flood led to about 75% of the recorded losses followed by earthquake with 17%, fire with 4% and landslides with 2%. The number of affected people is recorded as 62% due to flood and rain, 21% due to earthquake and 6% due to landslides. Mortality from natural hazards is highest from landslide and flood with each about 27%, followed by earthquake, volcanic eruptions and fire with each about 10%. The information is provided on municipality level.

The above information is useful as a guide, but historical disaster catalogues tend to be incomplete due to short recording periods and incomplete or inconsistent recording of event impacts. This can influence the number of events and total impact presented. Global risk indexes are limited in their utility to understand risk at a granular level, and no subnational risk index is available for Costa Rica from INFORM.

GENERAL OVERVIEW OF AVAILABLE RISK INFORMATION FOR COSTA RICA

This section describes the variety of risk information available to Costa Rica to get an initial understanding of the risk, outlined by category of source. Further down, the report examines the quantitative risk assessments by each specific peril affecting the country.

Local sovereign sources of risk information

Costa Rica's civil protection agency **CNE** operates a tracking and monitoring system (CNE 2024). It provides historic losses covering the years 2005-2023. The losses are provided per event on canton level for buildings and infrastructure. Overall, 92% of losses of all recorded events are registered as hydrometeorological and 6% as geological.

The **National Risk Forum**[2] in Costa Rica provides a comprehensive platform for discussing and advancing national risk management policies. It brings together the members of all the coordination bodies of the National Risk Management System to follow up on the national risk management policy on this issue. The Forum also provides a platform for information on advances in risk analyses, data, and overview of recent events.

The **SNIT**[3] mapping and data portal administered by the National Geographic Institute (IGN) brings together geographic information sourced from different systems and generated by many institutions of the public sector. The SNIT is the official platform through which fundamental geographic information is published in a standardised manner and following the technical standards used in the generation of geospatial information at the national level.

Instituto Meteorológico Nacional (IMN) Vulnerability Assessments

The IMN risk analysis studies[4] aim to describe climate risks based on vulnerability and hazards, focusing on hydrometeorological weather events such as droughts and heavy rainfall. The analyses are conducted at various geographical scales, including district and cantonal levels, and in several cases even higher resolution. The risk is assessed based on hazard and vulnerability and results are provided semi-quantitatively with five risk levels. The focus is on population including a disaggregation of input data by for example age or mobility restrictions. Although the reports do not cover the entire country, or provide potential losses, the high granularity of the assessments and input data is highly valuable and could be used as a foundation for future quantitative losses estimations with higher resolution or differentiated by population groups.

A recent study by Garro-Quesada et al. (2023) of rainfall-related risks for two specific municipalities, Cartago and Turrialba, based on the IMN risk assessment methodology but adding an exposure component, highlights differences in risk at a very localised level. While urban areas generally have higher risk due to greater exposure and vulnerability, for rural areas the dominant factors for risk stem from the hazard, e.g. rainfall or storm and limited infrastructure. The study emphasises the importance of considering local context in climate risk assessments.

Although the reports do not cover the entire country, or provide information on potential losses, the high granularity of the assessments and input data is highly valuable and could be used as a foundation for future quantitative estimation of losses with higher resolution, differentiated by population groups (e.g. rural vs urban).

[2] URL.
[3] URL.
[4] URL.

UNDRR Global Risk Assessment Framework (GRAF)

Costa Rica's Comisión Nacional de Emergencias (CNE) was an early adopter of the Global Risk Assessment Framework (GRAF) developed by UNDRR to help sovereign institutions reduce risk. The GRAF is a global framework for developing, sharing, and using risk information across hazards, disciplines, and geographic scales. CNE is the lead institution for GRAF in Costa Rica, and its work has provided a firm foundation of information governance and data on which the Global Risk Modelling Alliance and Global Shield can now build.

The GRAF's Systemic Risk Analysis for Costa Rica includes assessments of the country's exposure to earthquakes and floods and the potential direct impacts to physical assets and indirect impacts to the wider economy. Direct physical losses, such as damage to buildings and infrastructure, are calculated in a first step which then in turn are used as an input to estimate losses to production, employment, GDP, trade, and household consumption. Direct losses from earthquake predominantly affect residential buildings, educational centres, and the transport system, particularly in urban areas. The estimated losses are highest in San Jose and Alajuela. Indirect losses from earthquake are highest in the production sector and strongly affect employment. According to the assessments, losses in GDP can be predominantly expected through direct infrastructure losses.

Losses from flood also strongly affect residential buildings and the transport system. The regions that are impacted the most are Puntarenas and Limon. Indirect losses from floods are smaller than from earthquake and more localised. Most affected by floods are the agricultural and transport sectors.

Exposure data available for Costa Rica

Each of the risk modelling exercises have created exposure databases which provide an estimate of the total value (replacement value) of physical assets in the country, and its distribution at a specific administrative level. Typically, these databases are based on top-down modelling, using socio-economic, building type and capital stock data at a national or sub-national scale which are then transposed, or downscaled, onto a higher-resolution grid, using data such as geographic population or GDP distribution as approximation. Other efforts try and combine global top-down approaches with regional or local bottom-up approaches where they exist, e.g. GEM. Differences must be considered when comparing estimates of losses or using loss metrics for the development of CDRFI solutions. Using loss ratios, i.e. normalising by exposure value and thus calculating losses as percentage of the exposed total value can be helpful for better comparison

Table 3 provides an overview of the estimated capital stock for the different risk profiles, and which elements are included in the exposure databases. The wide range of estimates can partly be explained by the selection of elements included in each study. However substantial differences can also be attributed to methodology, which would need to be considered when selecting a source.

The two most recent estimates (Coalition for Disaster Resilient Infrastructure (CDRI) & GRAF) are quite similar for building stock with 97 US$bn and 101US$bn respectively. Differences stem from the incorporation of fewer infrastructure elements in GAR and thus a much lower total for infrastructure exposure (US$8bn vs. US$54bn). The estimation of indirect losses in other words the impacts on the wider economy as is done in the GRAF report are based on the direct losses. Leaving out critical elements when calculating direct losses could thus affect also the estimation of economic losses.

Table 2. Estimates of total capital stock (not corrected for inflation) for Costa Rica

Risk Profile	Year	Exposure value in US$ bn	Included	Specific infrastructure elements included
CAPRA	2012	85	Buildings and infrastructure	
GAR	2015	140	Buildings	
WBCDRP	2017	80	Buildings	
GEM	2018	136	Buildings with content	
CCRIF	2023	175	Buildings and infrastructure	Airports, power plants, water, energy, roads
CDRI	2024	151 (97+54)	Buildings and infrastructure	Land-based transport (roads, railways, bridges, tunnels), telecommunication lines, energy, water-utilities, ports and airports, oil and gas facilities
GRAF	2024	109 (101+8)	Buildings (excluding commercial and industrial) and key infrastructure	Water utilities pipelines, treatment plants, energy transmission lines, energy generation plants, roads

Exposure estimates differ substantially in existing risk profiles. The wide range remains between different estimates when normalising for the exposure (Figure 2, Average Annual Loss (AAL) ratio from 0.11 to 0.62% per capital stock). The variations between the estimates of losses are therefore not a consequence of variations in exposure value estimates but a different view of risk. The analyses with higher estimates of losses also generate the highest loss ratios. Looking at the three most recent profiles, (CCRIF, CDRI, GRAF) the relative differences become smaller and can be explained with the incorporation of different infrastructure elements in the estimates.

Commercially available quantitative risk models

There is an active market for commercially licensed catastrophe risk models covering Central America for tropical cyclone, earthquake and flood. Such models may have been produced to support indemnity insurance instruments, infrastructure investment projects or for other commercial purposes. The advantage of commercial catastrophe models is that they are generally produced to insurance standards and so have substantial funding, expertise and computer power behind them. This can bring advantages including higher resolution and a higher volume of simulations for probabilistic modelling. However, these features come with restrictions of use, and a price tag, for the model itself and sometimes also for licensed use of the modelling platform.

The **Caribbean Catastrophe Risk Insurance Facility (CCRIF)** offers parametric insurance products for excess rainfall (XSR3.0), earthquakes (Spera Model EQ), and tropical cyclones (Spera Model TC).

The Insurance Development Forum's CatRiskTools[5] catalogue shows models voluntarily listed by some leading model vendors. Further unlisted commercial models exist.

[5] URL.

Table 3. Extract from IDF CatRiskTools showing voluntarily listed commercial models for Costa Rica

Organisation	Model Name	Primary Hazard	Countries	License
AIR	AIR Tropical Cyclone Model for Central America	Cyclone	Central America, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua	Commercial License
AIR		Earthquake	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama	Commercial License
CoreLogic	Central and South America Hurricane	Cyclone	Costa Rica, El Salvador, Guatemala, Honduras, Colombia, Venezuela (Bolivarian Republic of)	Commercial
CoreLogic	Central and South America Hurricane	Earthquake	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Argentina, Brazil, Chile, Colombia, Ecuador, Peru, Venezuela (Bolivarian Republic of)	Commercial
ERN Evaluación de Riesgos Naturales	R-PLUS	Cyclone	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama	Commercial License
ERN Evaluación de Riesgos Naturales	R-PLUS	Hurricane	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama	Commercial License
ERN Evaluación de Riesgos Naturales	R-PLUS (Flood model)	Surface water flood (pluvial)	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama	Commercial License
ERN Evaluación de Riesgos Naturales	R-PLUS (Cyclone module)	Cyclone	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama	Commercial License
ERN Evaluación de Riesgos Naturales	R-PLUS (Tsunami module)	Tsunami	Costa Rica, Guatemala, Honduras, Mexico, Nicaragua, Panama, Chile, Colombia, Ecuador, Peru	Commercial License

Available flood hazard maps

Aqueduct Floods[6] is an online platform that measures riverine and coastal flood risks under both current baseline conditions and future projections in 2030, 2050, and 2080. In addition to providing free hazard maps and assessing risks, Aqueduct Floods enables its users to conduct comprehensive cost-benefit analysis to evaluate the value of dike flood protection strategies.

Fathom's Global Flood Map[7] provides its users with a robust and comprehensive set of hazard data and flood risk information across all major flood perils: pluvial, fluvial and coastal.

[6] URL.
[7] URL.

CLIMATE CHANGE ANALYSIS

Overview

Costa Rica faces significant climate change challenges in the coming decades, with projections indicating substantial shifts in temperature across all regions, precipitation decline and increasing extreme weather event frequency across various regions. By 2050, a sea level rise of 25 cm is expected, further endangering coastal regions. Nawrotzki et al. (2023) focus on identifying areas within Costa Rica that are most vulnerable to climate change, using a sub-national climate vulnerability index. The study reveals that both rural and urban areas are affected. Rural agricultural cantons like Los Chiles, Matina, Talamanca, and Buenos Aires are highly exposed due to the hazard component while certain urban cantons like Tibás and San José also show elevated levels of risk, driven by population density, economic inequality, and/or strain on public services. The results align with Quesada-Roman (2022) who created a flood risk index on municipal scale for all 82 cantons/municipalities in Costa Rica (now 2 cantons more). Higher flood risk values mostly occur in flat lands and coastal regions.

Temperature Change

By 2050, average temperatures in Costa Rica are projected to rise by 1.25°C to 1.75°C compared to the 1950-2014 period, with potential increases of 1.5°C to 4°C by the end of the century (WB, 2021). The National Meteorological Institute projects that by 2070, temperatures could increase by 3-6°C compared to 1961-1990 averages.

Precipitation Changes

Rainfall patterns are expected to increase in variability. Most regions particularly in the Northwest Pacific, the Central Valley and Caribbean region may see up to 25% less rainfall in the coming decades (IMN 2021). Conversely, parts of the Central Pacific might experience increased annual rainfall. These shifts are likely to result in more frequent and intense droughts interspersed with periods of heavy precipitation.

Most Affected Regions

- Guanacaste: This northwestern province is expected to see the greatest relative changes for both precipitation (reduction) and temperature (increase). The region will thus become more susceptible to droughts. Agriculture in the region faces additional challenges from changing seasonality of precipitation.
- Caribbean Coast: This area could experience decreases in rainfall and increase in temperature also affecting drought conditions. It's also prone to risks from tropical cyclones and floods.
- Central Areas: The most populated region of the country might see some increases in rainfall along the coast, the central valley could experience reduced precipitation.
- Montane Forests: Higher elevations are expected to face shifts in temperature and cloud base height, impacting ecosystems that rely on specific climatic conditions. The cloud forests in Monteverde, for example, may experience a loss of nebula, affecting their biodiversity and attractiveness as a tourism destination

For the estimation of risk, the change in precipitation variability will be most important. Changes in both extremes, i.e. dry and wet, will thus increase risk of drought and flood. Some regions will be more affected than others implying the necessity for regionally differentiated risk assessments, in particular as information source for the development of suitable climate and disaster risk finance instruments.

Climate change impacts

Climate change is having significant impacts across multiple sectors in Costa Rica. Based on stakeholder engagement within the GRMA programme and on the information available in the above-listed resources, the sectors most affected include:

Agriculture

Agriculture is expected to be one of the most affected sectors from climate change in Costa Rica. Changes in temperature and precipitation are likely to alter drought conditions and rainfall patterns. This will impact crop yields and suitable growing areas and affect production of for example bananas, coffee, beans, potatoes, rice, and others (WB, 2021). Estimates of direct agricultural losses, i.e. yield losses, are not included in the quantitative estimations of losses listed below indicating not sufficient publicly accessible information available for the design of CDRFI solutions.

Infrastructure

Both climate-related and geological hazards adversely affect Costa Rica's infrastructure. The Global Risk Assessment Framework (GRAF) project (see also below) has a particular focus on infrastructure as a result of stakeholder prioritisation in Costa Rica. Similarly, infrastructure was identified as a priority sector during the GRMA workshops (GRMA 2024). I.e., road infrastructure can be damaged by extreme precipitation, landslides, and rising temperatures. This in turn will affect other sectors, e.g. transport or tourism and will have an impact on the wider economy. Water systems, sewers, and bridges already require significant repairs due to climate-related events. Coastal flooding can damage port infrastructure which is vital for both local and international trade. Tropical cyclones can affect the country's energy grid, damaging power lines and distribution networks, especially in rural areas (WB 2021, NAP 2022, GIZ IKI[8]).

Energy

Costa Rica relies strongly on hydropower with over 70% of production. Increased rainfall variability particularly dry spells affect river flows likely leading lower river levels, thus impacting energy production. Increased temperature and evaporation can further reduce reservoir levels which may stress the system in a similar way that more evaporation can lead to lower river levels which in turn can lead to reduced hydropower production. (WB 2021, OECD 2023).

Tourism

The tourism sector, a crucial part of Costa Rica's economy, faces several climate-related risks. Increased frequency and intensity of climate-related events cause direct losses (for example loss of infrastructure and property) and indirect losses (short term business interruption, and long term harm to income attributable to environmental loss) Rising air temperature might increase operational costs and rising sea temperatures affect marine biodiversity and thus reduce the offer of recreational activities (GIZ 2017). The region with the highest tourist activity along the northern and central Pacific is projected to experience the greatest changes in temperature and rainfall with climate change.

Biodiversity and Ecosystem Services

Costa Rica is known worldwide for the exceptional richness and diversity of its natural resources. In addition to many other advantages, these resources have economic value that can be described in terms of ecosystem services. Costa Rica's Forest Law recognizes four environmental services provided by forest ecosystems: (i) mitigation of GHG emissions; (ii) hydrological services, including provision of water for human consumption, irrigation, and energy production; (iii) biodiversity conservation; and (iv) provision of scenic beauty for recreation and ecotourism.

The value of these services will be affected by climate change, and ecosystem indicators already show potential biodiversity shifts in the near future, mostly due to increasing temperature and water scarcity. These shifts are likely to occur at higher elevations, affecting the distribution of species and ecosystem services in the cloud forest. Coastal ecosystems are already impacted by tropical storms and flooding, and impacts will be further amplified by sea level rise. Marine biodiversity is strongly affected by increased sea temperatures (WB 2021, OECD 2023, Copernicus 2019).

Initial desk research suggests that these potential ecosystem impacts have not been modelled over climate timescales; if so, this is a significant information gap in future economic planning.

Summary

Among the several sectors that are impacted by climate-related hazards and climate change, infrastructure has been the central topic of many risk estimates and programmes (see also below) because of its vital role for the economy. Other sectors such as agriculture have received less attention possibly because the registered losses from drought are of a smaller magnitude. A systematic analysis of water scarcity, reduced river flows, and the subsequent impact on hydrological energy production seems missing. Potential losses caused by climate-related impacts on biodiversity and ecosystem services, either direct or the effect on the wider economy have not been quantified. The economic value of ecosystem services would have to be estimated.

SUMMARISED QUANTITATIVE RISK ESTIMATES PER MAJOR PERIL

This section provides a brief overview of different hazards relevant for Costa Rica and their likelihood affecting each province within the country. Table 2 shows seven quantitative assessments profiling physical asset losses due to Flood, Tropical Cyclone and/or Earthquake. (see Table 2). Note: the summary of estimates of losses has been provided through a forthcoming World Bank report on disaster risk of Costa Rica's infrastructure.

Table 4. Quantitative risk analysis projects since 2012

Acronym (incl. year)	Name	Flood	Tropical Cyclone	Earthquake	Source
CAPRA 2012	Comprehensive Approach to Probabilistic Risk Assessment			X	URL
GAR 2015	UNDRR Global Assessment of risk	X	X	X	URL
WB 2017	World Bank Climate Disaster Risk Profile		X	X	URL
GEM 2018	Global Earthquake Model Foundation			X	URL
CCRIF 2023	Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company	X		X	Shared from forthcoming WB report
CDRI 2024	Coalition for Disaster Resilient Infrastructure - Global Infrastructure Risk Index	X	X	X	URL
GRAF 2024	UNDRR and CNE Global Risk Assessment Framework	X		X	URL

Flood

According to the Global Facility for Disaster Risk Reduction (GFDRR) Platform ThinkHazard[9] the risk for flood in Costa Rica is high. This is true for riverine, urban, and coastal flooding including tsunamis. Urban flood risk is high across the entire country. Riverine flood risk is high in the North and along the Caribbean coast, medium in the San Jose province, low in Puntarenas, and very low in Cartago. This is generally aligned with the view of risk of the Aqueduct Water Risk Atlas[10] by the World Resources Institute. According to the Water Risk Atlas the risk of riverine flood is very high in the Heredia province and Northeast of the country and very high for the South of the Puntarenas Province. According to ThinkHazard the risk for coastal flood is high along the Pacific coast and medium along the Caribbean coast. The Water Risk Atlas estimates coastal flood risk to be low for Costa Rica.

[9] URL.
[10] URL.

Quantitative estimates of flood risk

Some globally produced research provides a helpful background for understanding flood risk in Costa Rica. These include the Global Assessment of Risk (UNDRR GAR, 2015), flood estimate conducted by CCRIF (2023), the Global Infrastructure Risk Index (GIRI) model from the Coalition for Disaster Resilient Infrastructure (CDRI, 2024), and the Global Risk Assessment Framework (GRAF) Costa Rica project (UNDRR and CNE, 2024).

The values of average annual losses (AAL[11]) range between US$ 16mn and US$193mn (Figure 1). The four different model estimates of losses include two lower values (GRAF 2024, US$16mn and GAR 2015, US$40mn) and two higher estimates (CDRI 2024, US$170mn and CCRIF 2023 US$193mn). The AAL ratio[12] (i.e. normalised by capital stock) ranges from 0.02% to 0.14% whereby the ranking between the estimates remains.The CCRIF estimate is based on an excess-rainfall model, rather than a flood model. In the GAR 2015 model, only larger rivers are modelled, and off-floodplain flooding is not considered, meaning that many locations at risk of flooding may not be captured. The flood hazard model used in the GRAF 2024 project is the same as used in GAR 2015, i.e. would have the same shortcomings.

Flood

Tropical cyclone risk from wind is medium in the North and East and low in other parts of the country, according to ThinkHazard.

Quantitative estimates of tropical cyclone risk

Three quantitative estimates of losses to physical assets exist, namely from GAR2015, World Bank Climate Disaster Risk Profile 2017, and CDRI GIRI 2024. The estimates of losses from tropical cyclones (wind and storm surge) ranges $0.04mn to $0.25mn for buildings only and $82mn for buildings and infrastructure. The AAL ratios follow the absolute estimates of losses.

Earthquake

The earthquake risk is high in the entire country (ThinkHazard). The newest version of the Probabilistic Seismic Hazard Assessment from 2022 as described in Hidalgo-Leiva et al. (2023) contains one of the most updated information data bases regarding seismic parameters. The results show extremely high risk for the Nicoya, Osa, and Burica peninsulas, very high risk for most of the Guanacaste Province, and high risk for about 41% of the country including Central Costa Rica and the capital city of San Jose.

Quantitative estimates of tropical cyclone risk

There are seven quantitative risk estimates for earthquake available from the last 12 years. Additionally, an estimate from CAPRA (2012) and GEM (2018) exists (see Table 1). The estimated AAL from earthquakes ranges from US$90mn to US$407mn for buildings only, or US$166 to US$526 when including infrastructure (Figure 1), or an AAL loss ratio of 0.09% to 0.62% of the total capital stock (Figure 2).

A systematic review of existing earthquake models and their usability for risk assessments or the development of CDRFI solutions will be conducted under GRMA with results to be expected in Q2 in 2025.

[11] Average Annual Loss (AAL) is the long-term expected loss per year, averaged over many years to model the losses for e.g. parametric insurance. AAL is an indication of the amount of savings a nation needs to set aside each year to cover the cost of long-term losses from that hazard.
[12] AAL ratio is the AAL per US$ exposure value. How much of every dollar that is exposed can be expected to be lost. This way different estimates of losses can be made more comparable as the effect of different totals for capital stock is excluded by normalising AAL with capital stock.

Figure 1: Average Annual Loss (AAL) for earthquake and flood in different risk profiles

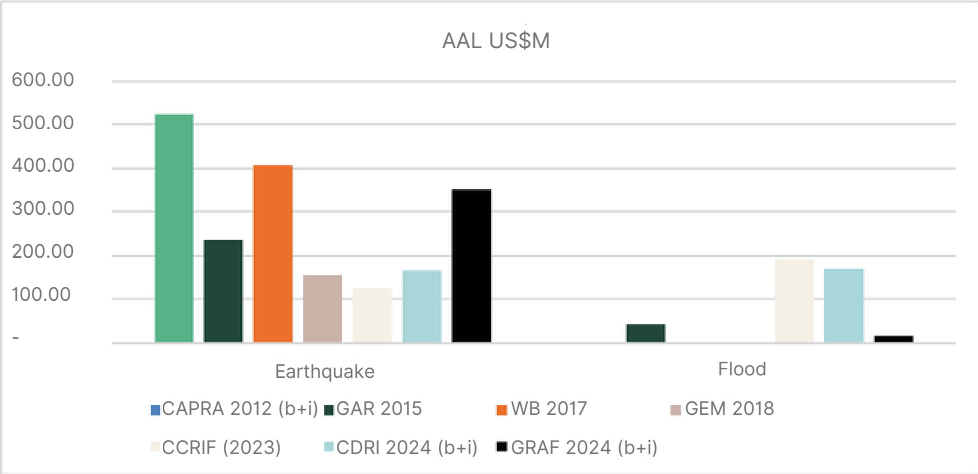
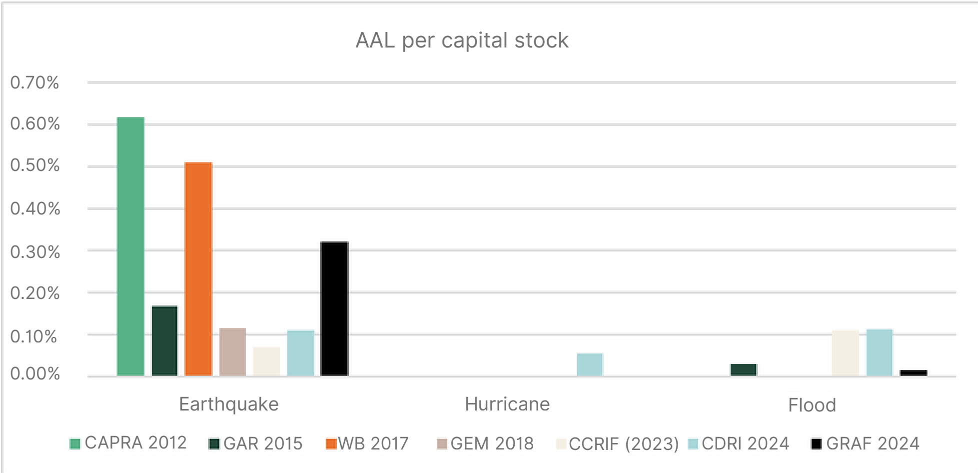


Figure 2: AAL ratio (AAL normalised for exposure) for earthquake and flood in different risk profiles



Drought

Heat risk is medium in the entire country. Water scarcity is low or very low (ThinkHazard 2024). The Water Risk Atlas (2024) estimates the risk for drought high in the Northwest, medium in the North, and medium low in the rest of the country.

Landslide, volcano, and wildfire

ThinkHazard provides the following estimates:

- Landslide risk is high in the entire country.
- Wildfire risk is high in west and south of the country and medium in all other parts of the country.
- Risk from volcanic ashfall is high Puntarenas and Limon and medium in all other parts of the country.

A systematic review of existing landslide and volcano ashfall models and their usability for risk assessments or the development of CDRFI solutions will be conducted under GRMA with results to be expected in Q2 in 2025.

IDENTIFIED GAPS IN DATA, MODELS, AND ANALYSES

This section outlines gaps identified in this review of the risk information landscape in Costa Rica. This information was used in the co-definition of the GRMA project with local stakeholders, to ensure GRMA adds value in the availability and use of risk information and that projects are aligned with local priorities and needs.

Recommendations for focus areas to address the identified gaps are provided, in three categories: (i) Understanding and interpretation of existing risk estimates (ii) Refinement of existing risk information; and (iii) Development of new risk estimates for specific hazards and sectors:

Category 1: Understanding and interpretation of existing risk estimates

1. Investigating the differences of existing probabilistic model results from risk profiles. This should include an analysis of the uncertainties in existing risk estimates. There are very recent estimates from GRAF, CDRI, and CCRIF which differ particularly for flood. A detailed comparison of estimates of losses, including the understanding of uncertainties and different exposure estimates, could be conducted.

2. Investigate which of the models and modelling approaches used in existing risk estimates are robust enough to be used for CDRFI solutions for Costa Rica. Several views of risk and models exist specifically for the country and region (e.g. CCRIF) for at least the major hazards. This would require international markets to be confident in the modelled estimates of risk. Model evaluation would include scrutiny of model methodologies, provenance and completeness of source data, examination of assumptions, extent of model validation, treatment of uncertainty, and more.

Category 2: Refining existing risk information

3. Creation of a national risk data platform. A central, open catalogue of metadata to describe the characteristics and provenance of available models and data. A wide range of stakeholders would benefit from shared knowledge of what risk information is available, and where to find it. Descriptions should use standards-based metadata, and datasets developed for public good should be based on open-licensing principles wherever possible. This will allow easier collation, sharing, and extension of data sets, and facilitate cross-sectoral exchange and knowledge transfer. The practicality of easily finding existing datasets or the awareness of an existing dataset will make access to risk information more efficient. This includes all components for climate and disaster risk modelling, i.e. hazard, exposure, and vulnerability. This project could support a hosting organisation with the establishment of a new platform or enhance an existing one such as SNIT (SNIT's operational and legal capacity would need to be clarified).

4. Integration of number of affected people in risk estimates with disaggregated population data. None of the quantitative risk estimates includes an exposure layer of population data. With the information available in Costa Rica this could be achieved easily. Disaggregated population data would allow for a differentiation between number of affected people based on gender, rural or urban, income, etc., by different hazards.

5. Development of disaggregated estimates of losses to physical assets. Population-sensitive risk estimates have not been the focus of previous analyses. Integrating disaggregated population data into existing model frameworks would allow the refinement of previous estimates of losses based on gender, rural or urban, income, etc.

6. Estimation of losses on canton-level. Previous quantitative risk profiles provide estimates on province-level. Risk indicators exist on community level, for example through the risk studies of IMN. Estimates of losses on province level might not be sufficient for adequate local decision-making in a geographically diverse country like Costa Rica given the corresponding spatial variations in risk. Combining highly granular information on exposure and people could be combined with previous risk estimates. The GRMA is conducting a multi-hazard analysis of critical infrastructure in the canton of Heredia to demonstrate a framework for infrastructure risk assessment on spatially high resolution, including fluvial, pluvial, coastal flood, and earthquake risk. This framework could be applied to other cantons with support of the Global Shield.

7. Extension and refinement of risk estimates by including more exposure categories. For example, the GRAF project's exposure estimate does not include telecommunication lines, bridges, ports, or airports. The important role of ports for Costa Rica's economy is thus not reflected sufficiently in the current GRAF report. Losses from tropical cyclones to telecommunication lines are not accounted for either. A more complete exposure estimate would lead to more realistic estimates of economic losses since indirect losses depend on direct losses to physical assets.

8. Addition of more hazard models to existing risk estimates. The GRAF report only covers the hazards earthquake and riverine floods. Adding different existing hazard models, particularly for tropical cyclones, would allow for the estimation of indirect losses from these hazards within the same framework. Other hazards to be covered could be excessive rainfall or drought.

Category 3: Developing new risk estimates for specific hazards or sectors

9. Development of a drought model for estimation of losses, particularly in the agricultural sector. None of the quantitative risk profiles include drought as a hazard. The agricultural sector is included in the GRAF project; however, the greatest impact can be expected from drought conditions. Water scarcity and increasing temperatures can be expected in several regions of Costa Rica, and drought intensity and frequency will thus increase in future. A drought index or drought model is necessary for the development of CDRFI solutions. Through GRMA a drought model is being developed with a focus on the impact on coffee, sugar cane, and livestock for a region yet to be defined with partners in Costa Rica.

10. Development of a multiple-hazard risk assessment for water, sanitation, and health sectors supporting ongoing efforts of Acueductos y Alcantarillados (AyA) and their existing GIRA tool (Guía de Gestión Integral de Riesgos para ASADAS). Clinical services would also benefit from such an assessment. Key infrastructure elements of public water networks vulnerable to climate-related hazards could be identified or taken from the GRAF project. A further related element could include risk mapping of regions with water scarcity expected in future. This would be complementary with water resources management and climate change adaptation targets identified in the NAP.

11. Development of risk estimates for the energy sector (mainly hydropower) through water scarcity. About 75% of Costa Rica's energy production is based on hydropower. Changing rainfall amounts and/or rainfall seasonality can affect river water levels and in turn affect energy production. An assessment of existing and suitable hydrological models also used for riverine floods would precede the risk estimate.

12. Quantification of ecosystem services through their economic value and/or a biodiversity index for risk estimations. Risk understanding around ecosystem services options for financial de-risking was mentioned as an area of interest from a wide range of stakeholders within the GRMA project, but did not make the list of top priorities. Research into risk to natural capital would align with other active projects such as the Payment for Environmental Services Program and Conservation or Trust Funds under MINAE, such as Forever Costa Rica Association or Fonafifo. The value of ecosystems and biodiversity also prominently features in the NAP.

CONCLUSION

Costa Rica faces both climate-related and geological risk from several different hazards. Historical data records outlined in this report provide useful orientation but tend to be incomplete due to short recording periods and incomplete or inconsistent recording of event impacts, particularly before the start of CNE's tracking and monitoring system in 2005. Although the records of collated events on number of affected people and economic losses from disaster differ between observational data bases, there is agreement that flood and tropical cyclones have so far led to the greatest monetary losses. However, quantitative risk profiles of potentially frequent and infrequent, yet still plausible, events reveal earthquake as the hazard potentially causing greatest losses.

Flood and tropical cyclones can be considered the most important climate-related hazards however risk from drought, landslide, volcanic activity, and wildfire remain important. Continuous climate change could alter the importance of different hazards and will likely lead to greater impacts from drought and flood through excessive rainfall. Risk models for the major climate-related hazards, i.e. flood and tropical cyclone are available or currently being developed by for example CCRIF. In the GRMA project an additional view of risk through pluvial, fluvial, and coastal flood model will further be developed. A systematic overview of existing earthquake, landslide, and volcano models is also carried out under the GRMA.

All but one of the quantitative risk profiles produced over the past decade focus on direct losses to physical assets, e.g. buildings or roads. The GRAF risk analysis extends these estimates with a systemic model of the economy by also calculating indirect losses from flood and earthquake to socio-economic variables e.g. export volume, GDP or wages. The risk estimates to physical assets differ particularly for flood. Some of these differences stem from the use of different models and/or different exposure value estimates.

There is a significant amount of risk information available in Costa Rica. The National Forum or initiatives like SNIT led by CNE, the risk analysis studies led by INM, and others plus a plethora of academic articles on climate and disaster risk provide a great risk data base for the country. Most of the information available on natural hazard risk focus on localised hazard mapping or more generalised risk indexes, rather than estimates of losses and damages, which are necessary for the development of CDRFI solutions.

Having identified gaps in the risk information landscape, the GRMA programme in Costa Rica is progressing some the above recommendations, namely risk estimatation specific to the agricultural, tourism, and road infrastructure sectors, and co-developing a canton-level risk assessment. Through these projects GRMA is enhancing technical capability in risk analysis and implementation of risk information in decision-making.

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