



Risk Assessment and Capacity
Development in Costa Rica

Probabilistic Risk Estimation for MSME Hotels and Hostels at the National Level

October 2025

Prepared for:



Prepared by:



Global Risk Modelling Alliance

InsuResilience Solutions Fund

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Probabilistic Risk Estimation for MSME Hotels and Hostels at the National Level

Product 5

(Deliverables 8c, 8d, 8e)

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1 INTRODUCTION

The Global Risk Modelling Alliance (GRMA), supported by the InsuResilience Solutions Fund (ISF), aims to strengthen the capacity of countries and cities to conduct climate and disaster risk analyses with a focus on financial decision-making. The initiative seeks to fill critical gaps in modelling and data, thereby enhancing climate and disaster risk assessments at both national and sub-national levels.

To achieve this goal, the GRMA works closely with local partners to identify and jointly define each country's specific needs, providing open-access risk management tools, data resources, and operational expertise in risk financing.

In Costa Rica, the GRMA has established a collaboration with the government—through its institutions under the leadership of SUGESE—to strengthen national capacities for climate risk management. This partnership will deliver relevant models and analytical tools to inform the country's national strategies for risk financing and disaster risk mitigation.

The program is being implemented in phases, beginning with the assessment of specific needs and culminating in the integration of advanced risk-modelling tools into public policy frameworks.

The project is funded by Germany's KfW Development Bank and administered by Frankfurt School on behalf of the GRMA.

The INGENIAR–CIMNE Consortium was selected to provide risk modelling services within the framework of the collaboration between the GRMA and the Government of Costa Rica, through an application focused on four risk assessment projects:

- Strategic Project: Demonstration of risk assessment methodologies for critical infrastructure in Heredia.
- Operational Project 1: Disaster and climate risk assessment for road infrastructure – National Route 2 (RN2), Pan-American Highway.
- Operational Project 2: Flood and drought risk analysis for small and medium-sized agricultural producers.
- Operational Project 3: Exposure and risk assessment for small and medium-sized hotels and lodges participating in the Fu-turismo program.

Implementation is carried out through the CAPRA-ROBOT modelling platform, developed by INGENIAR, which will also serve as an educational tool within the Training Program that runs throughout the entire duration of the consultancy.

This report corresponds to Product 5 (Task 8 deliverable): Probabilistic Risk Estimation for MSME Hotels and Lodges at the National Level. It is therefore specifically associated with Operational Project 3, and addresses Deliverables 8c, 8d, and 8e of the Terms of Reference for this consultancy

The report presents the results of the probabilistic risk assessment for the hotel sector, considering the following hazards: earthquake, tsunami, coastal flooding, riverine flooding, and pluvial flooding — the latter three influenced by climate change.

This assessment builds upon and complements elements previously presented in earlier deliverables:

- Deliverable 2 describes the pre-existing seismic hazard model used in this assessment, which underpins the modelling of earthquake and tsunami hazards.
- Deliverable 3 details the exposure model and vulnerability functions applied to the hotel portfolio.
- Deliverable 4 presents the climate-related hazard models developed for coastal, riverine, and pluvial flooding.

1.1 Scope of Operational Project 3

Tourism is one of the main drivers of the Costa Rican economy, contributing significantly to national economic output and employment generation. This project aims to assess disaster risk for this sector in relation to riverine, pluvial, and coastal flooding, as well as earthquakes and tsunamis.

The project is structured around the activities outlined in Table 1, with the corresponding timeline presented in Figure 1. All activities identified as value-added components were directly agreed upon with the Technical Working Group of this project.

Table 1. Tasks of Operational Project 3

Activity	Description	Task in ToR	Deliverable in ToR
Sea level rise model (CC)	Projections of sea level rise will be incorporated for greenhouse gas emission scenarios consistent with the future meteorological forcing considered.	T2.1, T8.2	D2.1a–f
Cyclone model (storm surge and rainfall)	The influence of tropical cyclones on coastal flooding will be modelled.	T2.1, T8.2	D2.1a–f
Tsunami model	The influence of tsunamis on coastal flooding will be modelled.	Value added	
Hotel exposure	An exposure database of hotel buildings will be developed, focusing mainly on small and medium-sized enterprises.	T8.1, T8.3	D8a–b
Hotel vulnerability	Vulnerability functions for hotel buildings will be established, considering losses to buildings, contents, and business interruption, as far as available data allow.	T4.4	D4a–d
Risk assessment	Application of the methodologies presented herein to assess risk using actuarial metrics of catastrophe modelling.	T8.4	D8c–d
Risk indicators	Two risk indicators will be developed: one for individual hotel facilities and another for the tourism sector (at the cantonal level), to be published on the Fu-turismo platform.	Added value	
Result calibration	The analytical loss exceedance curve generated by the model will be compared with one constructed from historical event data to validate correspondence.	T8.4	D8c–d
Investment curve	As a value-added activity, a set of risk management measures will be evaluated to determine the optimal combination that reduces risk for fixed and increasing investment levels.	Added value	

Task	15 Jan 25	Month													15 Apr 26
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Operational Project 3: Exposure and Risk Assessment for Small and Medium Hotels and Lodges of the Futurismo Program															
Climate model															
Flood national model															
Sea level rise model (CC)															
Cyclones model (storm surge)															
Tsunami model															
Hotel exposure															
Hotel vulnerability															
Risk assessment															
Results calibration															
Risk indicators															
Investment curve															

Figure 1. Schedule of activities for Operational Project 3.

(Blue cells indicate implementation. Green cells indicate product delivery. The red cell indicates this deliverable – Deliverable 5.)

2 CATASTROPHIC RISK MODELLING METHODOLOGY

The probabilistic risk modelling aims to estimate the probability distribution of potential losses that may occur within a set of exposed elements following the occurrence of a hazardous event (Cardona, 1986a; b; c; 1989; 1990; Bernal et al., 2021). Probabilistic modelling therefore enables forecasting of future loss levels, taking into account the hazard characteristics of the territory and the uncertainty in their estimation, as well as the inherent vulnerability of the exposed elements and their corresponding uncertainty.

2.1 Conceptual Approach to Risk Modelling

Probabilistic risk modelling consists of determining the possible consequences that a set of exposed elements may experience as a result of hazardous events. Sound risk modelling is fundamental to building a sustainable and resilient development process, taking into account the trade-offs between potential losses and benefits. In other words, such a process can only be properly guided when the risk modelling is sufficiently robust—both in terms of the credibility of the expected impacts and its ability to support well-founded, technically sound decisions free from arbitrariness.

The probabilistic risk modelling procedure, considering the effects of climate change, can be summarized in general terms as illustrated in Figure 27.

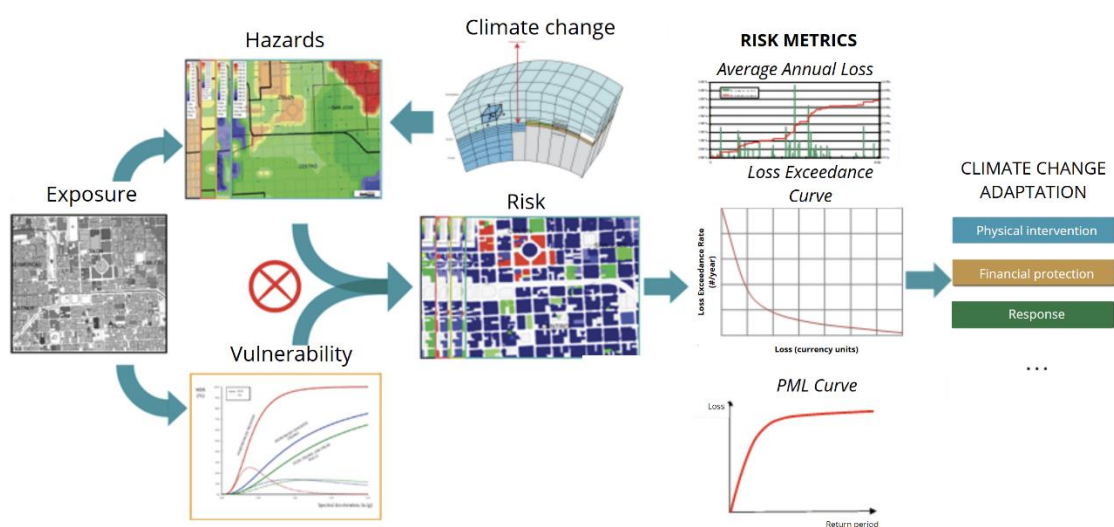


Figure 2. Components of the risk modelling and their relation

As illustrated in Figure 2, once the risk has been evaluated using actuarial metrics such as *Average Annual Loss* (AAL), *Loss Exceedance Curve* (LEC), and *Probable Maximum Loss* (PML), it becomes possible to establish an objective relationship between risk management measures and their effectiveness. In this way, the model can be used to design intervention strategies composed of multiple measures, whose risk reduction capacity can be quantitatively assessed.

Following the approach presented above, this study evaluates risk based on three fundamental factors:

- *Hazard*: defined as a collection of stochastically simulated events that are collectively exhaustive and mutually exclusive; that is, they encompass all possible ways in which the hazard may manifest, assuming independent events whose frequency of occurrence follows a natural power law (i.e., equivalent to a recurrence curve).
- *Exposed elements*: referring to the physical assets, infrastructure, or agricultural production that are exposed to the hazards and susceptible to damage or disruption under their influence.
- *Vulnerability of exposed elements* understood as the propensity or predisposition to be adversely affected. The assessment of vulnerability requires a specific model for each type of exposed element and each type of hazard—there is no single unified way to represent it. However, all models ultimately converge on the same metric for quantifying impact (economic loss), which makes the different models additive and comparable in terms of risk.

The first fully probabilistic approach to the risk problem from an actuarial perspective was proposed by Filip Lundberg in 1903 (Lundberg, 1903). In 1930, Harald Cramér formalized Lundberg’s theory into what is now known as Ruin Theory (Cramér, 1930). Lundberg defined an income–outcome model in which an insurance company starts its operations with a certain amount of capital, which increases over time as premiums are collected. At the same time, losses (claims to be covered by the company) occur randomly over time. If, as a result of paying these claims, the company’s capital falls below zero, the company goes bankrupt. Lundberg’s main interest was to determine the probability of insolvency of an insurance company.

Ruin Theory assumes that the occurrence of claims is not deterministic. Lundberg demonstrated that the occurrence of losses over time can be modelled as a Poisson process. Later, it was shown that any renewal process is valid within the framework of Ruin Theory (Andersen, 1957). A renewal process is a type of continuous-time, discrete-state stochastic process widely used across scientific and engineering applications, which represents the random occurrence of events over time. In this context, the events correspond to the occurrence of losses, regardless of their cause.

This is why the theory of ruin or insolvency is suitable for modelling any type of impact associated with a phenomenon, whether natural or otherwise, and can effectively inform risk management across other social, economic, environmental, and development contexts, beyond the insurance market itself.

A renewal process is defined by a single parameter—its intensity or rate. In risk assessment, this parameter corresponds to the loss exceedance rate, which is the inverse of the average time between the occurrence of events exceeding a given loss amount, p . Therefore, when assessing the risk of a portfolio of exposed elements (that is, the probability that a given loss p will be exceeded within a time window), its exceedance rate $\nu(p)$ must be computed based on the probability of occurrence of all possible hazardous events capable of causing that exceedance. This establishes a renewal process that allows for estimating the probability of exceeding loss p over any given period of time.

2.2 Risk Quantification

From a mathematical standpoint, risk modelling aims to characterize a random process of loss occurrence over time (i.e., a loss process). A loss process has several important characteristics that determine the risk modelling approach adopted in this study—an approach commonly used in the fields of actuarial

catastrophe modelling, safety and reliability engineering, and the aeronautical and aerospace industries, among others.

Risk is determined through the convolution of hazard and vulnerability, at the location of the exposed elements and for the entire portfolio of such elements. In the probabilistic calculation of losses, both hazard and vulnerability are represented probabilistically. The hazard has a probabilistic representation in both time and space. The temporal occurrence of hazard scenarios is modelled as a renewal process, which requires fitting a probability model to the time intervals between consecutive events.

The uncertainties associated with hazard and vulnerability are defined by their respective nature: temporal and spatial for the hazard, and intensity-dependent for the vulnerability. In this way, the main output of the model is a specific probability distribution of loss for each hazard event.

The probability density function (PDF) of the loss for the exposed element j , conditional on the occurrence of hazard event i (i.e. $f(p_j|E_i)$), is calculated as:

$$f(p_j|E_i) = \int_0^{\infty} f(p_j|s)f(s|E_i)ds \quad \text{Equation 1}$$

where the first term of the integral corresponds to vulnerability ($f(p_j|s)$), the probability density of loss given an intensity s), and the second term corresponds to the hazard ($f(s|E_i)$), the probability density of intensity given the occurrence of a hazard event).

The total loss of event i corresponds to the sum of all individual losses (p_j) of the exposed elements. Since these summands are random variables, the proper probabilistic arithmetic must be applied to determine the loss of event i . The summation is performed over the probability moments of the variables p_j , as shown below:

$$E(p|E_i) = \sum_{j=1}^{NE} E(p_j) \quad \text{Equacion 2}$$

$$\sigma^2(p|E_i) = \sum_{j=1}^{NE} \sigma^2(p_j) + 2 \sum_{\substack{k=1 \\ k < j}}^{NE-1} \sum_{j=2}^{NE} cov(p_k, p_j) \quad \text{Equation 3}$$

where $E(p|E_i)$ is the expected value of the loss for event i , $\sigma^2(p|E_i)$ is its variance; NE is the total number of exposed elements; $E(p_j)$ is the expected loss for element j , $\sigma^2(p_j)$ is its variance; and $cov(p_k, p_j)$ is the covariance between the losses of two different exposed elements.

From the probability moments of the aggregated event loss, a Beta probability model is fitted.

Risk is commonly described by the loss exceedance curve, which specifies the frequency of occurrence of events that exceed a given loss value. This annual exceedance frequency, which corresponds to the exceedance rate $\nu(p)$, is calculated as follows:

$$v(p) = \sum_{i=1}^N Pr(P > p|E_i) \cdot F_A(E_i) \quad \text{Equation 4}$$

where $v(p)$ is the exceedance rate for loss p , N is the total number of hazard events, $F_A(E_i)$ is the annual frequency of occurrence of event i , and $Pr(P > p|E_i)$ is the probability that loss p is exceeded, given that event i occurs. The summation covers all hazard events capable of generating losses.

The inverse of $v(p)$ represents the return period of loss p Tr , which is the expected time interval between events that exceed loss p :

$$Tr = \frac{1}{v(p)} \quad \text{Equation 5}$$

The loss exceedance curve contains all the necessary information to probabilistically characterize the process of loss occurrence associated with hazard events. Figure 3 shows an example of a loss exceedance curve.

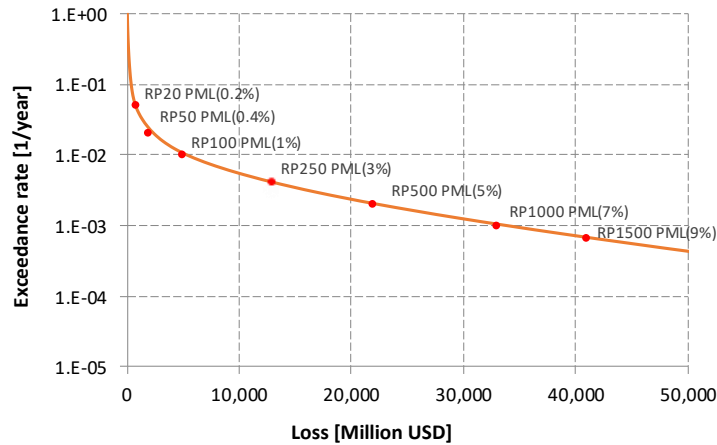


Figure 3. Example of a loss exceedance curve. The vertical axis shows the exceedance rate, and the horizontal axis shows the associated loss. (RP = Return Period; PML = Probable Maximum Loss).

The calculation performed using Equation 4 corresponds to the estimation of the exceedance rate for the loss amounts occurring across all exposed elements, for all events included in the hazard model, and for all hazards considered.

As shown in Figure 4, the probabilistic risk assessment can be summarized in the following steps: 1) For each hazard event, determine the loss for every exposed element, 2) Calculate the total loss caused by each event as the sum of the individual losses in all exposed elements, 3) Once the losses for all events have been quantified, compute the corresponding exceedance rates.

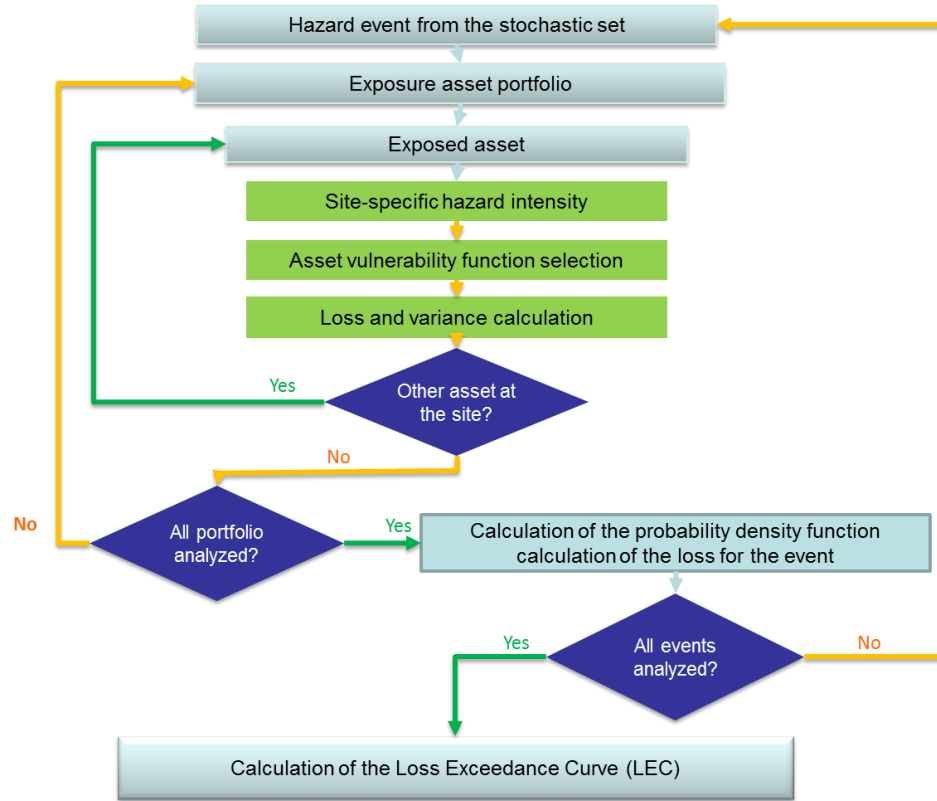


Figure 4. Flowchart of the probabilistic risk assessment

2.3 Risk Metrics

From the loss exceedance curve, various risk metrics can be derived, which are useful for different purposes within decision-making and risk management processes. These metrics provide an integrated representation of risk, typically condensed into one or a few indicators, rather than presenting the full set of event losses or the complete loss exceedance curve.

2.3.1 Average Annual Loss (AAL)

The AAL corresponds to the expected value of annual loss. It represents the average annual amount which, if accumulated over the long term, would be equivalent to the total of all future losses. The AAL can be interpreted as the pure annual premium that would fairly cover all potential losses occurring each year. It can be calculated as the area under the loss exceedance curve:

$$AAL = \int_0^{\infty} v(p) dp \quad \text{Equation 6}$$

Alternatively, from the set of event losses, the AAL can also be determined as:

$$AAL = \sum_{i=1}^N E(P|E_i) F_A(E_i)$$

Equation 7

where $(P|E_i)$ is the average loss for event i , and $F_A(E_i)$ is the annual frequency of occurrence of event i . The expected loss, given the occurrence of a particular event, depends on the vulnerability of the exposed elements.

The Average Annual Loss is an important indicator, as it integrates into a single value the effect, in terms of losses, of the occurrence of hazard events on vulnerable exposed elements. It is considered the most robust indicator of risk, not only because it summarizes the entire loss occurrence process into a single number, but also because it is relatively insensitive to uncertainty, as it represents the mathematical expectation of losses on an annualized basis.

2.3.2 Probable Maximum Loss (PML)

Although the main output of the risk assessment is the loss exceedance curve, the PML curve is often preferred, as it is generally easier to understand the concept of a return period, which—as mentioned earlier—is the expected time interval between events that exceed a given loss, and is mathematically equivalent to the inverse of the exceedance rate. The loss exceedance curve and the PML curve contain equivalent information.

From the PML curve, loss values can be determined for arbitrary return periods. The selection of a specific return period as a PML reference depends solely on the risk aversion of the decision-maker.

Figure 5 shows an example of a PML curve, where, from a selected return period on the horizontal axis — 400 years in this example— the corresponding loss value can be determined on the vertical axis. This indicates that such a loss would be exceeded on average once every 400 years.

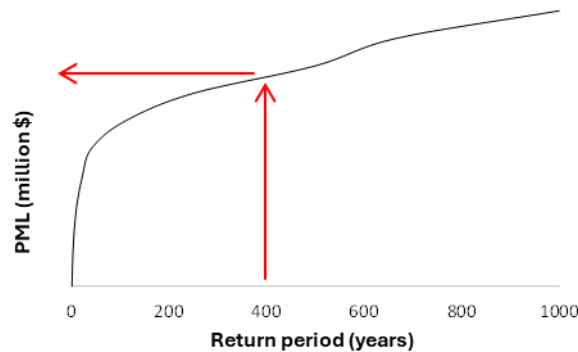


Figure 5. Example of a PML curve

2.4 Limitations of the Risk Assessment

This section presents some well-known limitations of probabilistic risk assessment, which are strongly related to the quality of the available data. It is important to note that the limitations described here are

complementary to those already discussed in the previous deliverables of this consultancy: the methodological framework presented in the Inception Report, the information on pre-existing geological hazard models (Deliverable 2), the exposure and vulnerability models developed as part of this consultancy (Deliverable 3), and the hydrometeorological hazard models with climate change components developed by the consultant (Deliverable 4). Therefore, this section does not seek to repeat what has already been presented, but rather to provide a general overview of the known limitations of probabilistic risk assessment.

Probabilistic disaster risk assessment critically depends on the availability and resolution of the data used to model hazards, exposure, and vulnerability. A common limitation is the scarcity of historical records of extreme events, which makes it necessary to simulate large and catastrophic events based on indirect information about the territory and the manifestation of phenomena. This lack of data prevents calibration and validation processes, since evidence of the occurrence of most simulated events does not exist—they simply have not yet occurred. This is particularly true under climate change conditions. Likewise, in the case of climate-related phenomena, hydrometeorological data often exhibit temporal gaps, low spatial density of stations, or inconsistencies caused by changes in measurement systems.

The characterization of exposure is naturally constrained by the absence of a detailed and up-to-date inventory of exposed assets (in this case, hotels), including critical variables such as construction typologies, occupancy levels, or replacement values. The lack of this information necessitates the use of generic typologies and assumptions, which introduce uncertainty. Similarly, vulnerability functions are typically derived from experimental or empirical studies conducted in other geographical or structural contexts.

Although Costa Rica stands out in the region for having well-structured and robust information systems that provide valuable inputs for modelling, there remain limitations inherent to the probabilistic approach. The main challenge lies in the fact that modelling is based on projecting future events that have not yet occurred, which involves reliance on analytical assumptions about the extreme behavior of natural phenomena and the response of exposed elements to them. Therefore, even in data-rich contexts such as Costa Rica, uncertainty cannot be eliminated—it must be explicitly managed within the risk assessment process.

2.4.1 Recommendations for Future Assessments

Based on the inherent limitations of the current assessment, several general recommendations are proposed to strengthen the future use of probabilistic risk assessment models:

Strengthen the registration and systematization of tourism assets

Tourism operators, transportation companies, theme parks, concessioned natural attractions, and other sector stakeholders should be encouraged to consolidate updated information on georeferenced location, construction characteristics, installed capacity, economic value of assets, and seasonal occupancy levels. This information supports a more accurate characterization of exposure in probabilistic models. Some of these efforts are currently being addressed through the Fu-Turismo platform.

Define representative construction typologies for the tourism sector

Identify and classify the various types of tourism-related buildings (for example: eco-lodges, beach hotels, resorts, rural cabins, recreation centers, and mountain facilities), including information on construction materials, structural systems, and maintenance conditions. This will enable the development or adaptation of more realistic and sector-specific vulnerability functions. The archetypes defined in this consultancy (Deliverable 3) provide a solid starting point for the typification of constructions within the sector.

Promote data sharing and interoperability between institutions

Facilitate the exchange of information among institutions involved in disaster risk management, climate monitoring, and tourism regulation. Establishing standardized data formats and metadata protocols would improve interoperability between systems and enhance the integration of probabilistic risk models at the national level.

Incorporate risk scenarios into tourism planning

Encourage tourism development and expansion plans to integrate the results of probabilistic risk assessments and future extreme event scenarios. This approach increases both the demand for and the practical usefulness of risk models, while promoting their continuous updating and improvement.

Build capacity among sector stakeholders in risk assessment concepts and their applications

Develop capacities that enable stakeholders to understand risk assessment methodologies and the benefits of this approach for business sustainability. This includes strengthening their ability to use these results in insurance decisions, investment planning, business continuity protocols, and access to financing.

3 RISK ASSESSMENT RESULTS

The risk assessment for the portfolio of hotels in Costa Rica produced the results presented below, expressed in terms of Average Annual Loss (AAL) and Probable Maximum Loss (PML), for the following hazards: riverine flooding (river overflow), pluvial flooding (surface water accumulation), coastal flooding (from tropical cyclones), and, as a value-added component, earthquake (at the national level) and tsunami (along the Pacific coast).

For earthquake and tsunami, the reported losses are not associated with future climate conditions. However, for the flood-related hazards (riverine, pluvial, and coastal flooding), climate change is incorporated, as it modifies or influences the occurrence of these hazards and therefore alters the corresponding risk metrics.

Details regarding the climate modelling and the integration of climate change effects into these hazards can be found in Product 4 of this consultancy (Task 2 deliverable: Climate Hazard Models). For riverine and pluvial flooding, three global circulation models (GCMs), four greenhouse gas emission trajectories, and three future time horizons were considered, resulting in a total of 36 possible future climate scenarios. The models, emission trajectories, and projection years used for riverine and pluvial flooding are summarized in Table 2, along with an abbreviated naming convention used in this document to identify the results associated with each climate scenario.

For coastal flooding, due to limitations in the availability of high-resolution climate projections (which are required to represent mesoscale meteorological phenomena such as hurricanes), a single model was used. This model corresponds to an ensemble of a few high-resolution models¹, for which parametrized projections to 2050 are available under the SSP5-8.5 emission pathway. Therefore, results related to future climate for coastal flooding are presented under the abbreviation HRMIP-SSP5-50.

Table 2. Future climate scenarios considered for riverine and pluvial flooding and their abbreviations

GCM	Pathway	Target year	Abbreviation	GCM	Pathway	Target year	Abbreviation
EC-Earth3	SSP1-2.6	2035	EC-SSP1-35	GFDL-ESM4	SSP3-7.0	2050	GFDL-SSP3-50
EC-Earth3	SSP2-4.5	2035	EC-SSP2-35	GFDL-ESM4	SSP5-8.5	2050	GFDL-SSP5-50
EC-Earth3	SSP3-7.0	2035	EC-SSP3-35	GFDL-ESM4	SSP1-2.6	2100	GFDL-SSP1-100
EC-Earth3	SSP5-8.5	2035	EC-SSP5-35	GFDL-ESM4	SSP2-4.5	2100	GFDL-SSP2-100
EC-Earth3	SSP1-2.6	2050	EC-SSP1-50	GFDL-ESM4	SSP3-7.0	2100	GFDL-SSP3-100
EC-Earth3	SSP2-4.5	2050	EC-SSP2-50	GFDL-ESM4	SSP5-8.5	2100	GFDL-SSP5-100
EC-Earth3	SSP3-7.0	2050	EC-SSP3-50	MPI-ESM1-2-LR	SSP1-2.6	2035	MPI-SSP1-35
EC-Earth3	SSP5-8.5	2050	EC-SSP5-50	MPI-ESM1-2-LR	SSP2-4.5	2035	MPI-SSP2-35
EC-Earth3	SSP1-2.6	2100	EC-SSP1-100	MPI-ESM1-2-LR	SSP3-7.0	2035	MPI-SSP3-35
EC-Earth3	SSP2-4.5	2100	EC-SSP2-100	MPI-ESM1-2-LR	SSP5-8.5	2035	MPI-SSP5-35
EC-Earth3	SSP3-7.0	2100	EC-SSP3-100	MPI-ESM1-2-LR	SSP1-2.6	2050	MPI-SSP1-50
EC-Earth3	SSP5-8.5	2100	EC-SSP5-100	MPI-ESM1-2-LR	SSP2-4.5	2050	MPI-SSP2-50
GFDL-ESM4	SSP1-2.6	2035	GFDL-SSP1-35	MPI-ESM1-2-LR	SSP3-7.0	2050	MPI-SSP3-50
GFDL-ESM4	SSP2-4.5	2035	GFDL-SSP2-35	MPI-ESM1-2-LR	SSP5-8.5	2050	MPI-SSP5-50
GFDL-ESM4	SSP3-7.0	2035	GFDL-SSP3-35	MPI-ESM1-2-LR	SSP1-2.6	2100	MPI-SSP1-100

¹ These models are CMCC-CM2-VHRA, CNRM-CM6-1-HR, EC-Earth3P-HR, and HadGEM3-GC31-HM, all of which are taken from the PRIMAVERA High Resolution Model Intercomparison Project (HighResMIP), a subproject of CMIP6. The ensemble projections mentioned above are also direct outputs obtained from HighResMIP.

GCM	Pathway	Target year	Abbreviation	GCM	Pathway	Target year	Abbreviation
GFDL-ESM4	SSP5-8.5	2035	GFDL-SSP5-35	MPI-ESM1-2-LR	SSP2-4.5	2100	MPI-SSP2-100
GFDL-ESM4	SSP1-2.6	2050	GFDL-SSP1-50	MPI-ESM1-2-LR	SSP3-7.0	2100	MPI-SSP3-100
GFDL-ESM4	SSP2-4.5	2050	GFDL-SSP2-50	MPI-ESM1-2-LR	SSP5-8.5	2100	MPI-SSP5-100

3.1 General Results for the Entire Hotel Portfolio

3.1.1 Average Annual Loss (AAL)

Table 3 presents a the complete list of the AAL values for the entire hotel portfolio of Costa Rica. The AAL is shown by hazard type, both in absolute monetary terms (in Costa Rican colones) and in relative terms with respect to the total exposed value of the portfolio, expressed in per thousand (‰). For reference, the total exposed value of the hotel portfolio is CRC 1,723,321 million (USD 3,516 million approximately)².

As mentioned previously, the AAL corresponds to the mean value of annual losses. That is, it represents the annual compensation value that would be required to offset, over the long term, the cumulative losses caused by events. For example, in the case of fluvial flooding under the baseline climate³, the absolute AAL amounts to CRC 1,679 million. This means that, if it were possible to compensate all losses to the hotel sector from riverine flooding on an annual basis under current climate conditions, the annual payment would correspond to this AAL amount.

This annual loss, when compared with the total exposed value of the portfolio, corresponds to 0.974 ‰, meaning that for every CRC 1,000 of value in the hotel portfolio, an average of 0.974 (approximately 1) is lost each year. This relative indicator allows the magnitude of the loss to be assessed in relation to the actual size of the portfolio. For the reader's reference, an AAL ratio of 1‰ lies at the upper limit of what the insurance market typically considers to be "insurable." The results obtained fall within what is reasonable and expected for this type of hazard and for a portfolio of hotel buildings.

Table 3. Average Annual Loss by hazard and climate scenario. Values in million Costa Rican colones (CRC)

Hazard	Climate	AAL (CRC)	AAL (‰)	Hazard	Climate	AAL (CRC)	AAL (‰)
Earthquake		927	0.538	Riverine flooding	MPI-SSP5-50	1,719	0.997
Tsunami		787	0.457	Riverine flooding	MPI-SSP5-100	1,916	1.112
Coastal flooding	Baseline climate	235	0.136	Pluvial flooding	Baseline climate	205	0.119
Coastal flooding	HRMIP-SSP5-50	164	0.095	Pluvial flooding	EC-SSP1-35	207	0.120
Riverine flooding	Clima base	1,679	0.974	Pluvial flooding	EC-SSP1-50	202	0.117
Riverine flooding	EC-SSP1-35	1,651	0.958	Pluvial flooding	EC-SSP1-100	203	0.118
Riverine flooding	EC-SSP1-50	1,635	0.949	Pluvial flooding	EC-SSP2-35	198	0.115
Riverine flooding	EC-SSP1-100	1,621	0.941	Pluvial flooding	EC-SSP2-50	202	0.117
Riverine flooding	EC-SSP2-35	1,596	0.926	Pluvial flooding	EC-SSP2-100	190	0.110
Riverine flooding	EC-SSP2-50	1,611	0.935	Pluvial flooding	EC-SSP3-35	196	0.114
Riverine flooding	EC-SSP2-100	1,566	0.909	Pluvial flooding	EC-SSP3-50	195	0.113
Riverine flooding	EC-SSP3-35	1,595	0.926	Pluvial flooding	EC-SSP3-100	179	0.104
Riverine flooding	EC-SSP3-50	1,560	0.905	Pluvial flooding	EC-SSP5-35	200	0.116
Riverine flooding	EC-SSP3-100	1,509	0.875	Pluvial flooding	EC-SSP5-50	195	0.113
Riverine flooding	EC-SSP5-35	1,599	0.928	Pluvial flooding	EC-SSP5-100	173	0.101

² Value calculated using the average exchange rate for December 2025, corresponding to 490 colones per U.S. dollar.

³ The baseline climate corresponds to the observed climate during the historical control period 1990–2020.

Hazard	Climate	AAL (CRC)	AAL (‰)	Hazard	Climate	AAL (CRC)	AAL (‰)
Riverine flooding	EC-SSP5-50	1,571	0.911	Pluvial flooding	GFDL-SSP1-35	207	0.120
Riverine flooding	EC-SSP5-100	1,469	0.852	Pluvial flooding	GFDL-SSP1-50	204	0.118
Riverine flooding	GFDL-SSP1-35	1,700	0.987	Pluvial flooding	GFDL-SSP1-100	204	0.118
Riverine flooding	GFDL-SSP1-50	1,664	0.965	Pluvial flooding	GFDL-SSP2-35	201	0.116
Riverine flooding	GFDL-SSP1-100	1,698	0.986	Pluvial flooding	GFDL-SSP2-50	198	0.115
Riverine flooding	GFDL-SSP2-35	1,656	0.961	Pluvial flooding	GFDL-SSP2-100	198	0.115
Riverine flooding	GFDL-SSP2-50	1,646	0.955	Pluvial flooding	GFDL-SSP3-35	200	0.116
Riverine flooding	GFDL-SSP2-100	1,625	0.943	Pluvial flooding	GFDL-SSP3-50	190	0.110
Riverine flooding	GFDL-SSP3-35	1,634	0.948	Pluvial flooding	GFDL-SSP3-100	174	0.101
Riverine flooding	GFDL-SSP3-50	1,577	0.915	Pluvial flooding	GFDL-SSP5-35	199	0.116
Riverine flooding	GFDL-SSP3-100	1,490	0.864	Pluvial flooding	GFDL-SSP5-50	192	0.111
Riverine flooding	GFDL-SSP5-35	1,643	0.953	Pluvial flooding	GFDL-SSP5-100	169	0.098
Riverine flooding	GFDL-SSP5-50	1,590	0.923	Pluvial flooding	MPI-SSP1-35	218	0.126
Riverine flooding	GFDL-SSP5-100	1,453	0.843	Pluvial flooding	MPI-SSP1-50	217	0.126
Riverine flooding	MPI-SSP1-35	1,804	1.047	Pluvial flooding	MPI-SSP1-100	230	0.134
Riverine flooding	MPI-SSP1-50	1,809	1.050	Pluvial flooding	MPI-SSP2-35	226	0.131
Riverine flooding	MPI-SSP1-100	1,927	1.118	Pluvial flooding	MPI-SSP2-50	242	0.141
Riverine flooding	MPI-SSP2-35	1,894	1.099	Pluvial flooding	MPI-SSP2-100	215	0.125
Riverine flooding	MPI-SSP2-50	2,050	1.190	Pluvial flooding	MPI-SSP3-35	220	0.128
Riverine flooding	MPI-SSP2-100	1,789	1.038	Pluvial flooding	MPI-SSP3-50	235	0.136
Riverine flooding	MPI-SSP3-35	1,836	1.065	Pluvial flooding	MPI-SSP3-100	214	0.124
Riverine flooding	MPI-SSP3-50	1,985	1.152	Pluvial flooding	MPI-SSP5-35	214	0.124
Riverine flooding	MPI-SSP3-100	1,780	1.033	Pluvial flooding	MPI-SSP5-50	207	0.120
Riverine flooding	MPI-SSP5-35	1,775	1.030	Pluvial flooding	MPI-SSP5-100	228	0.132

Figure 6 graphically presents the relative AAL values for all hazards, showing only the climate scenarios that produce the highest losses across the entire portfolio for each projection year, in the case of riverine and pluvial flooding.

As shown in Figure 6, the hazard that produces the highest AAL at the portfolio level is riverine flooding, with a maximum AAL of 1.19‰ relative to the total exposed value, under the MPI-SSP2-50 climate scenario. The seismic and tsunami hazards follow in importance in terms of total AAL, with values approximately 50% lower than those of riverine flooding. Finally, coastal and pluvial flooding show comparatively lower AAL values.

These results highlight the dominant role of riverine flooding in driving higher risk values in terms of AAL. The AAL is highly sensitive to high-frequency phenomena, which explains why riverine flooding—a hazard that occurs on an annual basis during the rainy season— produces the largest annual losses. In contrast, pluvial flooding, although also a recurrent annual phenomenon, generally occurs with significantly lower intensities, resulting in lower AAL values.

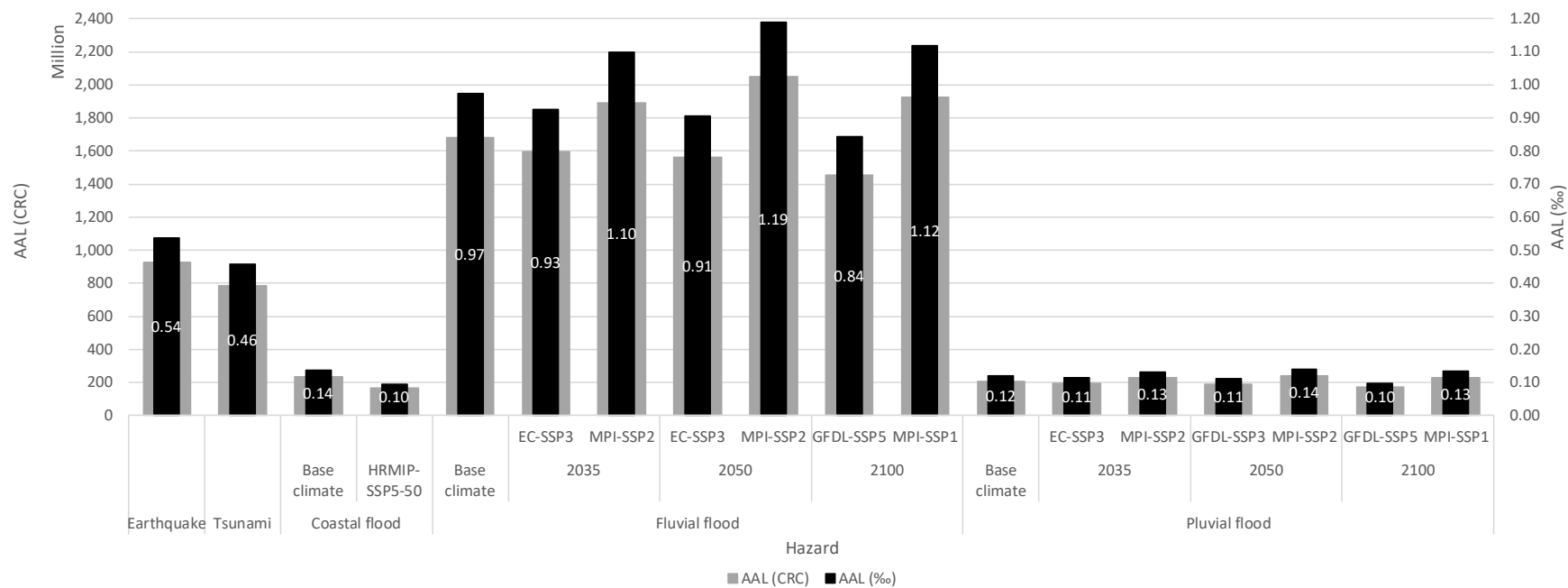


Figure 6. Average Annual Loss

As explained earlier, while Figure 6 presents the complete set of results for the earthquake, tsunami, and coastal flooding hazards, only the results for the baseline climate and three future climate scenarios are shown in the case of riverine and pluvial flooding. This was done to avoid overloading the figure.

Nevertheless, it is useful to examine the consolidated total AAL values for these two hazards, including all climate scenarios under which they were evaluated. Figure 7 shows the AAL as a function of time, where each line represents a different climate projection, that is, a combination of a GCM model and an emission pathway. This allows for observing the temporal evolution of flood risk when considering different climate models. Figure 8 presents the same information for pluvial flooding.

As observed, although the fluctuations in AAL values vary among the projection years, these variations do not follow an increasing trend over time or across emission pathways. In other words, risk does not necessarily increase with higher emissions, nor does it always grow toward the future. This behavior is entirely normal and expected, as the relationship between greenhouse gas emissions and risk is highly non-linear. Higher emissions do not necessarily imply greater risk; the outcome depends on the specific conditions of the hazards, exposure, and vulnerability, which mediate the manifestation of losses from hydrometeorological phenomena under each climate scenario studied.

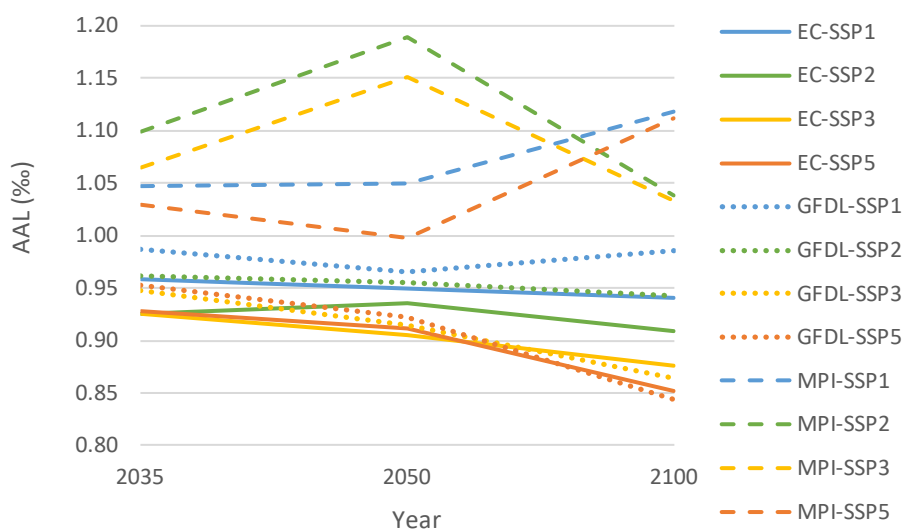


Figure 7. Average Annual Loss from riverine flooding for the climate change scenarios considered

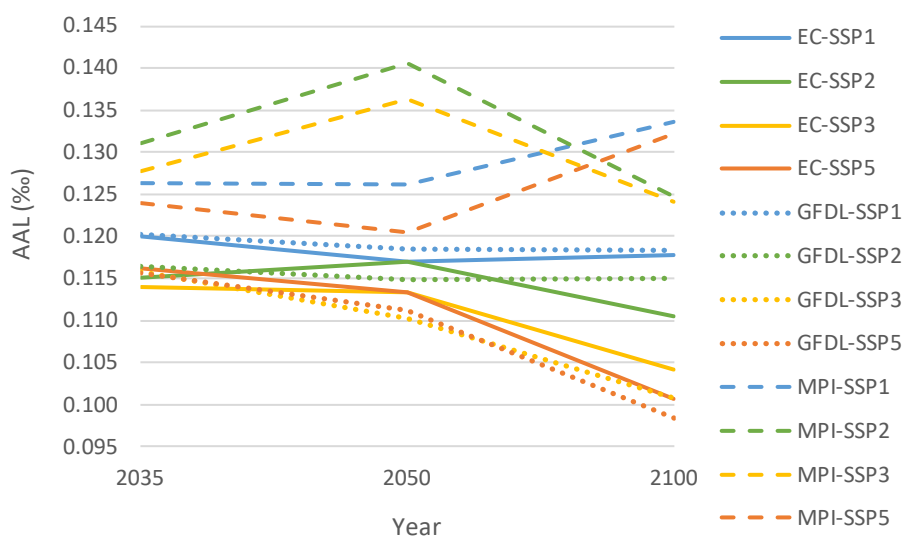


Figure 8. Average Annual Loss from pluvial flooding for the climate change scenarios considered

Figure 7 and Figure 8 illustrate the very high uncertainty inherent in risk modelling that incorporates climate change projections. Each line shown represents a possible trajectory of risk evolution. However, it is impossible to know which of these trajectories will actually materialize in the future—or even whether the real risk levels in 2035, 2050, or 2100 will fall within the range of the scenarios analyzed. This condition is referred to as deep uncertainty, as defined in Section 5.5 of the Inception Report.

When risk is treated under deep uncertainty, point-based metrics such as the AAL become interval-based metrics, meaning that they are inherently imprecise in nature.

In such imprecise risk metrics, it is not possible to define a probability distribution within the range of variation of the metric—only the upper and lower bounds of that range. As shown in Figure 7 and Figure 8, the maximum and minimum AAL values for each projection year, resulting from different combinations of GCM models and emission pathways, represent the bounds of the metric for those years. These bounds define the AAL variation interval, which itself changes over future time periods in accordance with the evolution of greenhouse gas concentrations under the multiple trajectories considered.

As can be observed, the relationship between emissions and risk is strongly non-linear, as it is mediated by territory-specific factors such as soils, vegetation cover, topography, basin response, among others, as well as by the vulnerability of the exposed elements, all of which are factors independent of climate. In the Costa Rican case, some of the future climate scenarios considered project reductions in national-scale precipitation volumes by 2100, which translates into a tendency toward reduced flood risk. It should be noted that, although this tendency appears relatively clear across the ensemble of climate models considered, some models do project increases in precipitation volumes, thereby increasing flood risk. In the context of climate change, it is not possible to assert that any given model is projecting future climate conditions correctly, particularly over long-term horizons such as the year 2100.

In the short to medium term (2035–2050), some models—particularly MPI and EC under certain scenarios—project transient increases in PAE, suggesting a relative intensification of the

hydrometeorological conditions that control flood risk. However, toward the end of the century (2100), most model–scenario combinations tend to stabilize or even reduce PAE, especially under the SSP1 and SSP2 scenarios, while higher-emission scenarios exhibit more heterogeneous and model-dependent responses. This dispersion indicates that model-specific uncertainty dominates over the emission scenario signal, and that differences in the representation of meteorological variables across models play a decisive role in risk estimation.

It is also observed that these intervals become wider in future years. Although this is not necessarily a fixed trend for all portfolios and all hazards, since emission pathways tend to cover a broader range of variation in later projection years (further evidence of the large uncertainty embedded in the models), it is common for the AAL variation interval to increase over time. In other words, as uncertainty in climate projections increases further into the future, risk metrics also exhibit wider uncertainty ranges.

Finally, similar patterns can be seen in the risk projections for riverine and pluvial flooding, since both are triggered by the same underlying phenomenon—precipitation—and the climatic influence on that trigger is the same in both cases. Although the absolute loss values differ, the shape of the projections reflects this common origin.

3.1.2 Probable Maximum Loss (PML)

As mentioned in Section 2.3.2, PML curves are an alternative way of presenting loss exceedance curves. They are complete representations of portfolio risk, encompassing both frequent, lower-loss events and rare, high-impact catastrophic events. Expressing the curve in terms of the return period allows for a clearer and more intuitive communication of the risk level associated with events across the entire frequency spectrum, that is, ranging from very frequent events to rare events with a low probability of occurrence.

Figure 9 shows the PML curves for all hazards and climate scenarios considered in this assessment. In these graphs, the PML is presented in relative terms, as a percentage of the total exposed value. This curve illustrates the increasing nature of loss as a function of return period, that is, how losses increase for events with progressively lower frequencies.

Two general types of behavior can be observed in the PML curves: *i)* Gradually increasing curves with respect to return period, without a tendency toward stabilization, which are typical of low-frequency hazards such as earthquakes, tsunamis, and coastal flooding⁴; and *ii)* Rapidly increasing curves at short return periods that stabilize clearly, showing nearly constant values at longer return periods—typical of high-frequency hazards such as riverine and pluvial flooding.

⁴ Since the triggering phenomenon of coastal flooding in Costa Rica is hurricanes, it is important to note that although hurricanes occur annually in the oceanic basins, they are relatively low-frequency events for Costa Rica.

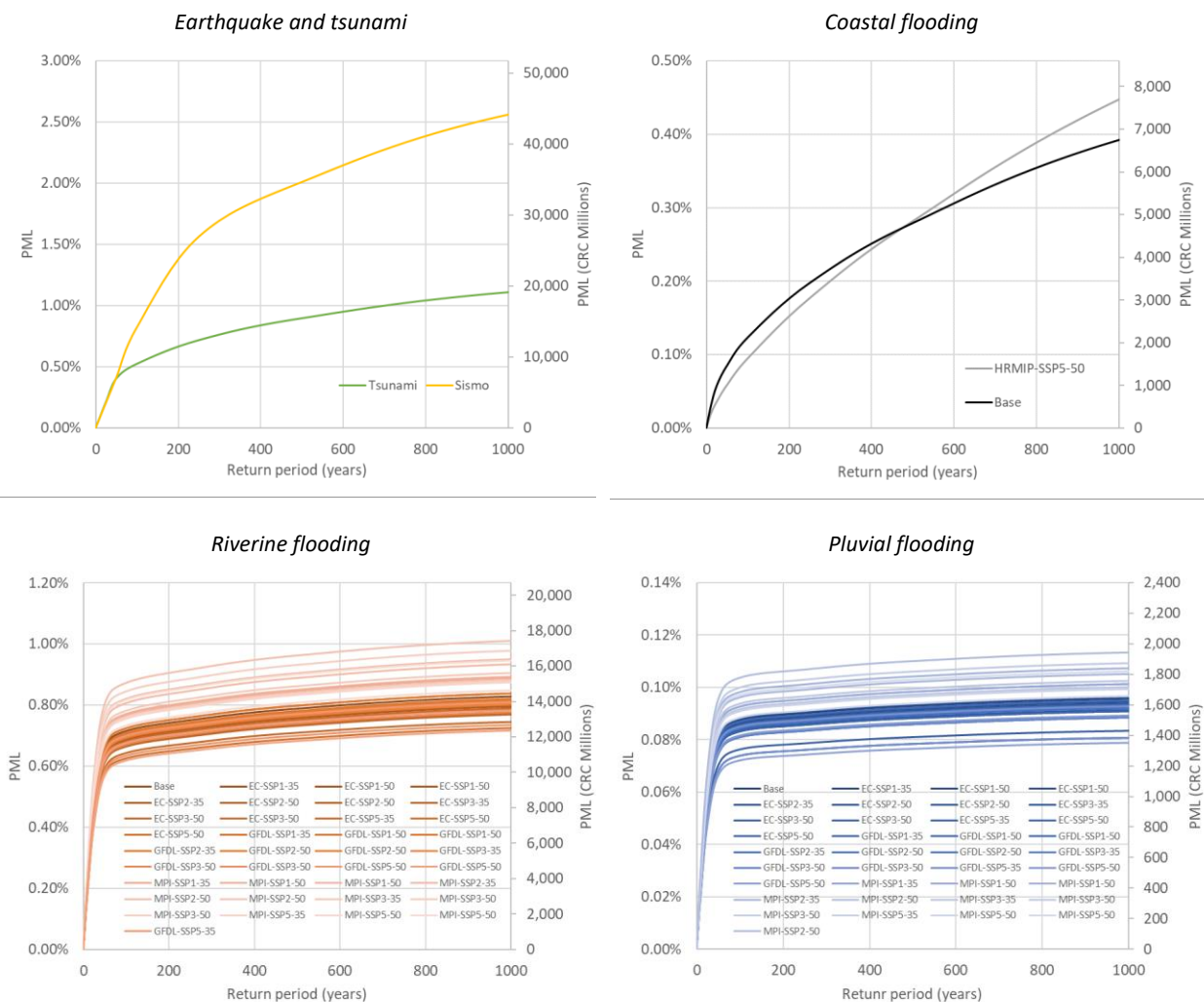


Figure 9. PML curves for all hazards and climate scenarios considered

The PML figures for different return periods are included in Annex A.1 for all hazards and climate scenarios considered. Both absolute values (in CRC) and relative values with respect to the total exposed value of the hotel portfolio, which, as mentioned earlier, amounts to CRC 1,723,321 million, are presented.

Figure 10 shows a comparison of the PML curves for all hazards, displaying only the climate scenarios with the highest AAL in each future projection year for riverine and pluvial flooding. This selection was made because including all 36 future climate scenarios for these hazards in a single figure would make proper comparison impossible.

The comparison of the PML curves illustrates the type of curve behavior, which—as mentioned previously—depends on the frequency of event occurrence. It is evident that earthquakes are the hazard producing the highest PML values at long return periods, significantly exceeding those of all other hazards. This implies that earthquakes have the capacity to correlate losses across multiple locations, thereby causing large aggregated losses for low-frequency (long return period) events.

It can also be observed that riverine flooding, under any of the climate scenarios, while not reaching as high loss values at long return periods, exceeds earthquakes at very short return periods. This is due to the relatively high frequency of flood events, which also explains why the AAL values presented earlier are higher for riverine flooding than for any other hazard, including earthquakes.

It can further be concluded that, for long return periods, riverine flooding generates loss magnitudes similar to those of tsunamis, meaning that catastrophic events from these hazards can produce comparable losses under current exposure and vulnerability conditions. Likewise, when considering long return periods, coastal flood risk is low, and pluvial flood risk is very low, which is a consistent and expected result.

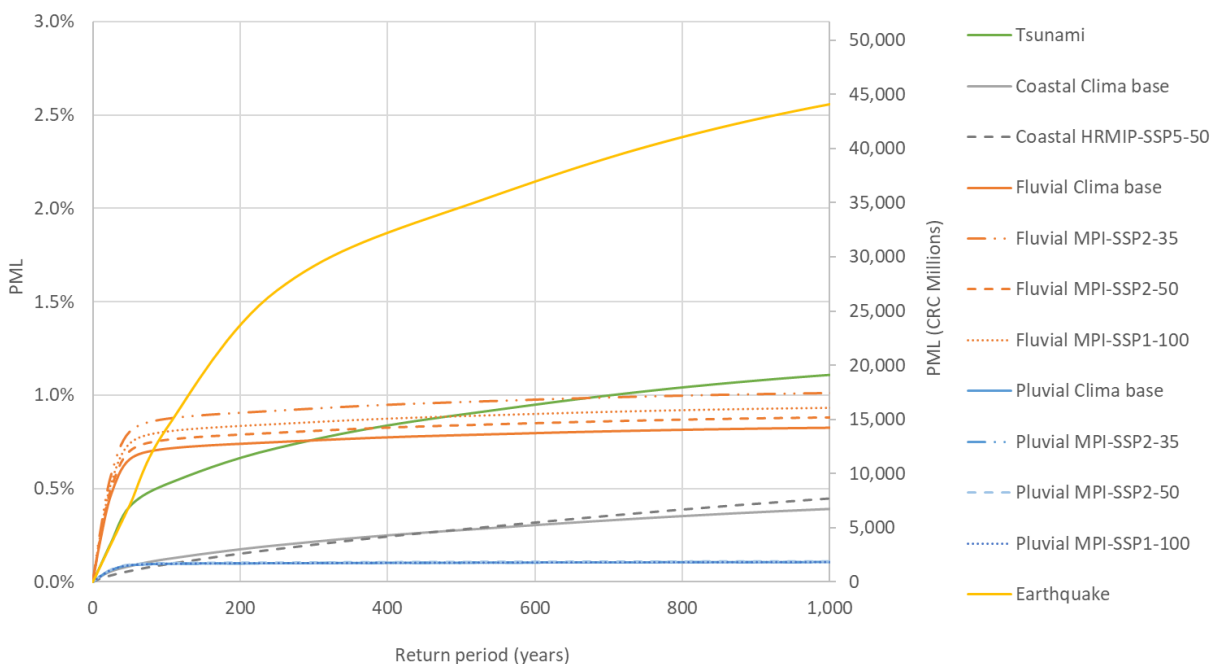


Figure 10. Comparison of PML curves for the hazards considered and selected climate scenarios

3.2 Results by Location

The results presented above are useful for assessing the risk of the hotel sector as a whole, from a portfolio perspective, to inform sector-level risk management decisions, and are particularly valuable for the design of financial protection instruments intended to cover the entire sector.

However, portfolio-level results do not illustrate what occurs at the individual level for each hotel in terms of the specific risk it faces. For each of the 2,006 hotels included in the exposure database, risk was evaluated in terms of Expected Annual Loss (AAL). Only the AAL is presented, as it is the only risk metric that can be disaggregated to the level of individual locations⁵.

The maps shown in Figure 11 through Figure 15 display the spatial distribution of the AAL (per thousand, relative to the exposed value of each hotel) at the national level for all hotels included in the assessment. Due to space constraints, AAL results are shown for all hazards, but only under the baseline climate for climate-influenced hazards. However, the complete set of results is included in the project dataset.

Hotel locations are represented as points to facilitate nationwide visualization. Nonetheless, polygon data defining the spatial footprint of each hotel across the country are also available.

⁵ Although it is mathematically possible to disaggregate the PML by location, the uncertainty in such estimates is too high, and therefore this disaggregation is not performed. The portfolio-level PML, on the other hand, benefits from a reduction in total uncertainty as a result of the law of large numbers, by aggregating many exposed elements into a single outcome. For this reason, the PML is reported only at the portfolio level.

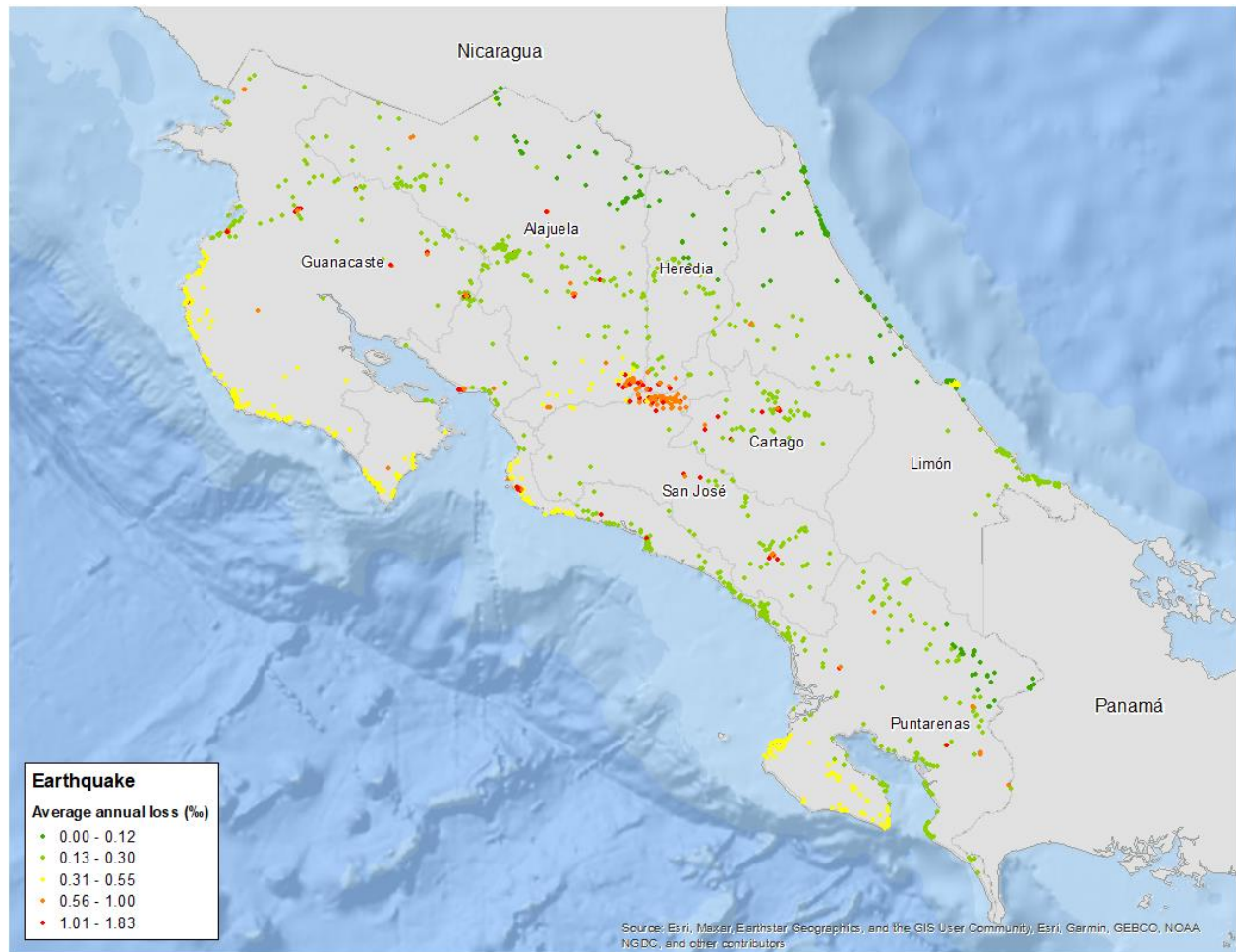


Figure 11. Average Annual Loss from earthquakes for hotels

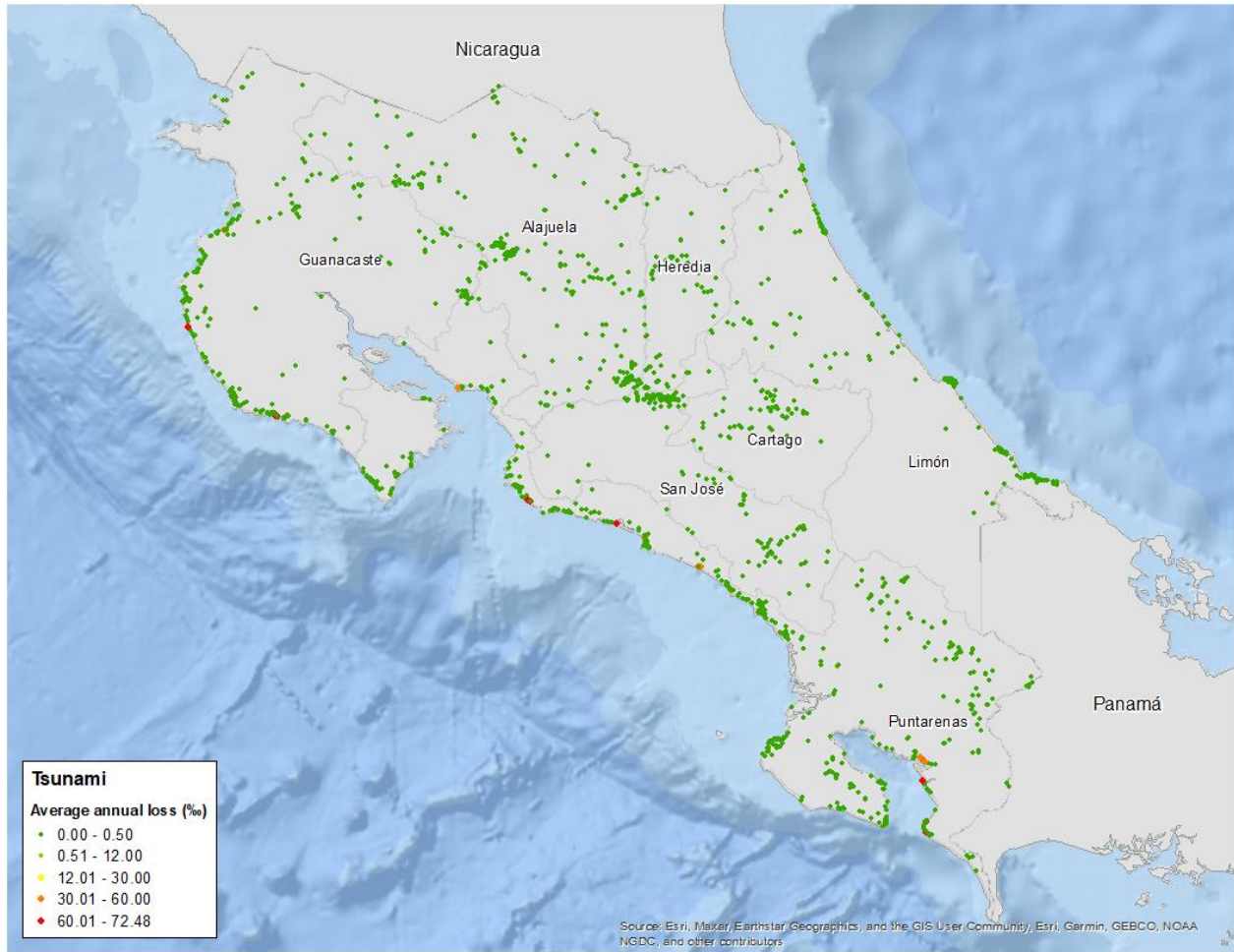


Figure 12. Average Annual Loss from tsunami for hotels

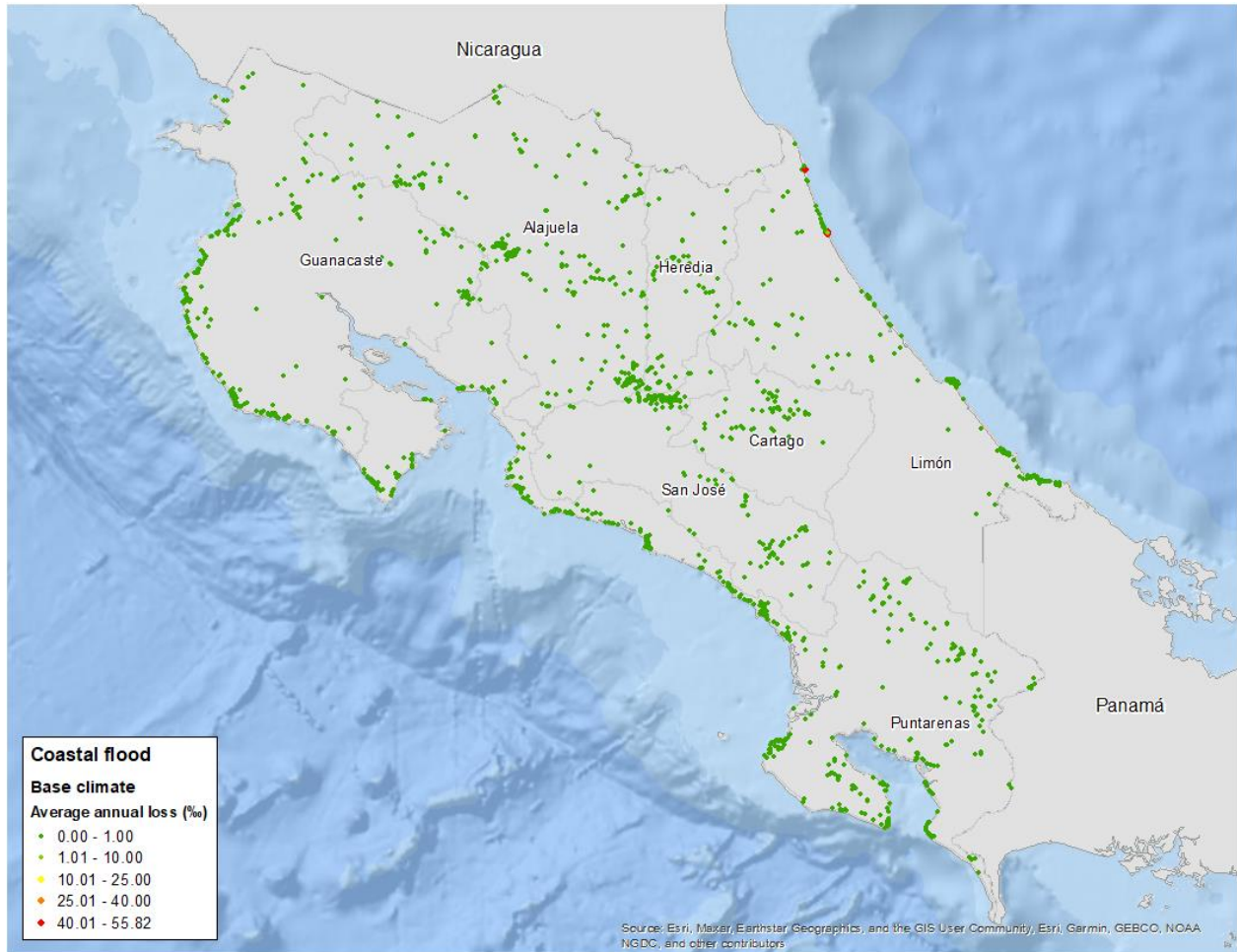


Figure 13. Average Annual Loss from coastal flooding (baseline climate) for hotels

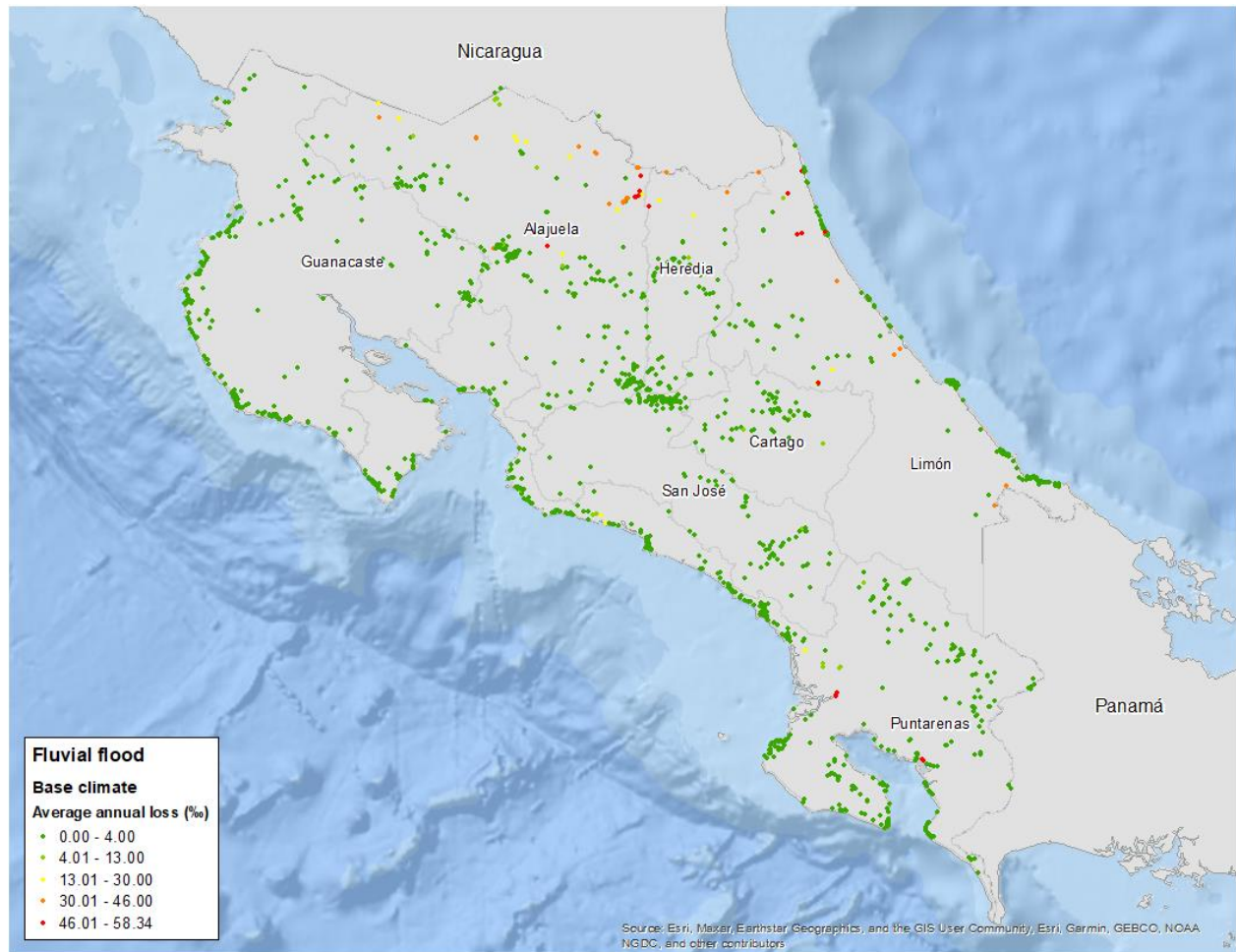


Figure 14. Average Annual Loss from riverine flooding (baseline climate) for hotels

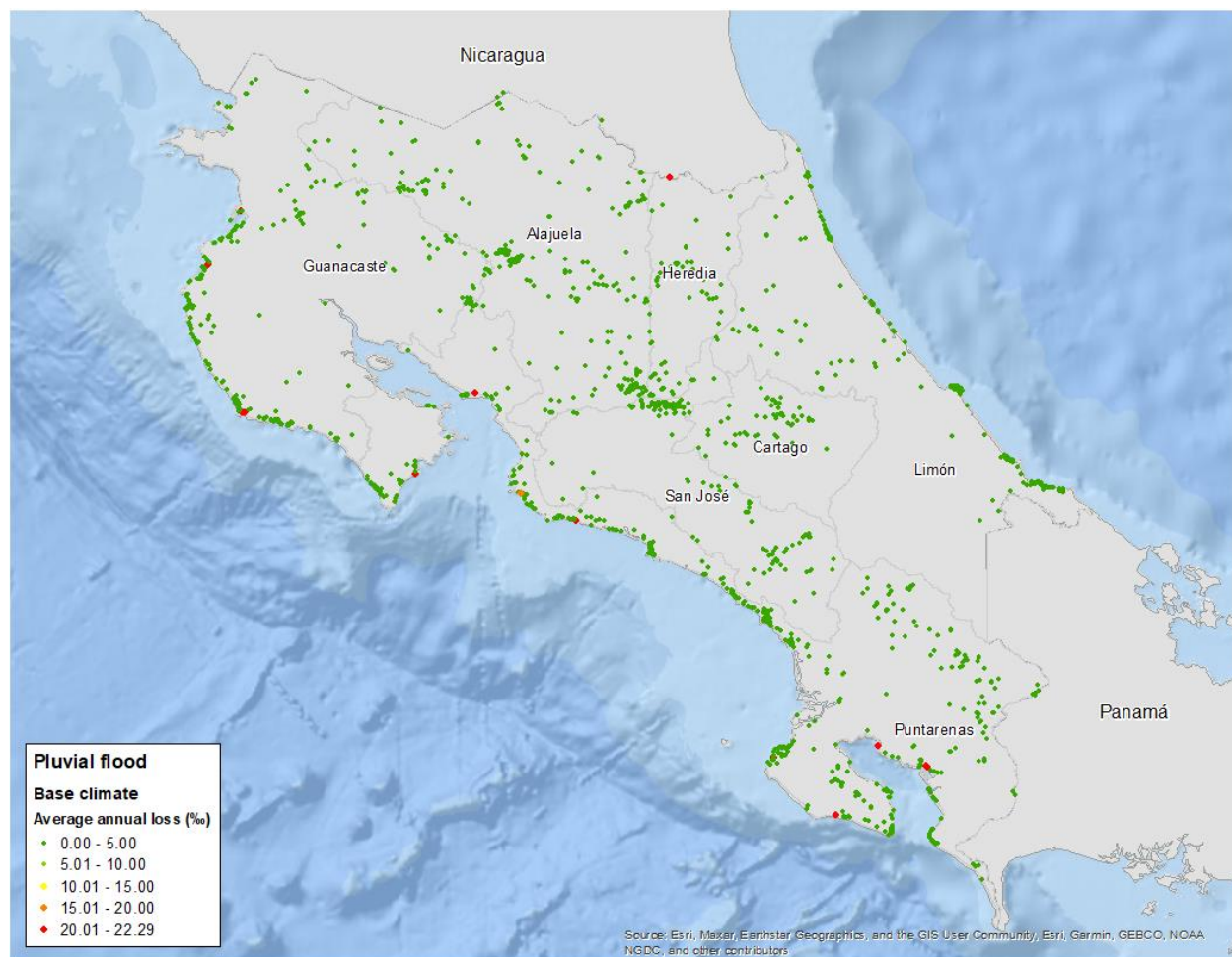


Figure 15. Average Annual Loss from pluvial flooding (baseline climate) for hotels

As observed, the loss distributions differ significantly among the hazards considered, which is to be expected. For instance, earthquakes (Figure 11) produce notably higher loss correlations, as they represent a hazard capable of affecting 100% of the hotel portfolio, given that the entire territory of Costa Rica is, to some degree, exposed to seismic events. This explains the very high PML values obtained when compared with other hazards.

However, when examining individual hotel values, the maximum AAL is 1.83%, which is considerably lower than the maximum point losses recorded at specific locations for all other hazards—including pluvial flooding, which represents the lowest overall portfolio risk. The maximum point values for these hazards were 72.48‰ for tsunami, 55.82‰ for coastal flooding, 58.34‰ for riverine flooding, and 22.29‰ for pluvial flooding (the latter three under the baseline climate).

The above illustrates that, although earthquakes can correlate losses across multiple locations in a single event—thus representing one of the most significant risk levels for the sector—the individual losses sustained by each hotel are highly variable. There are locations where other hazards may be much more critical, in terms of risk, than earthquakes.

In the maps presented, it is possible to observe areas along the Caribbean coast that are strongly affected by coastal flooding (Figure 13), as well as locations along the Pacific coast that show high risk levels due to tsunamis (Figure 12). These hazards—as well as riverine and pluvial flooding—do not correlate losses across a large number of assets in each event but can exert significant influence on individual elements in specific locations, where high hazard intensity combined with high vulnerability results in unusually elevated AAL values.

The results presented are inevitably dominated by the frequency–severity relationship inherent to each hazard. Earthquakes are capable of producing very large impacts in individual events, but with a very low frequency of occurrence, which contrasts with phenomena such as flooding, for example, whose impacts are much smaller at the level of individual events but occur with much higher frequency. This explains the relationships observed among the losses associated with these hazards, and with all those considered in this study.

As mentioned earlier, the exposure database developed for this study includes footprint polygons for all hotels considered. The previously shown maps do not display this feature because, when visualizing the entire country, individual elements cannot be clearly distinguished. Nevertheless, Figure 16 through Figure 18 present example maps of annual loss for earthquake, tsunami, and coastal flooding, to illustrate this situation. These maps include zoomed-in views of selected areas of the country, where the true level of detail of the calculated risk information can be appreciated.

Analyzing losses element by element is crucial for other risk management processes, such as those aimed at reducing local and individual vulnerability, modifying exposure (for instance, through infrastructure relocation), and designing hazard mitigation works (such as riverine or coastal flood protection structures). These data complement the portfolio-level results by providing a more comprehensive understanding of how risk values are spatially distributed, and by identifying specific areas where targeted interventions could effectively reduce vulnerability.

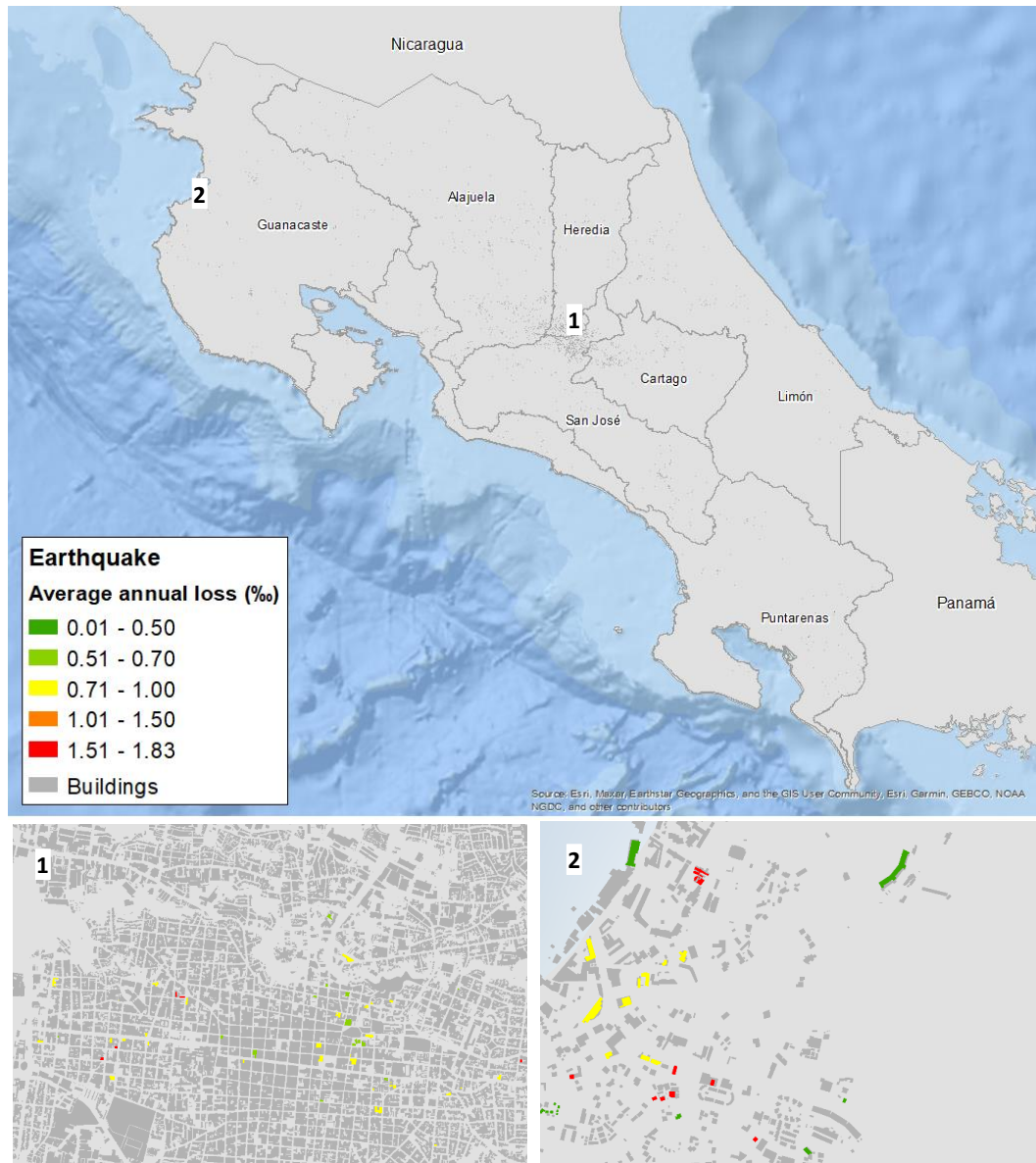


Figure 16. Average Annual Loss from earthquake for hotels represented as polygons. Zoom 1: San José. Zoom 2: Santa Cruz.

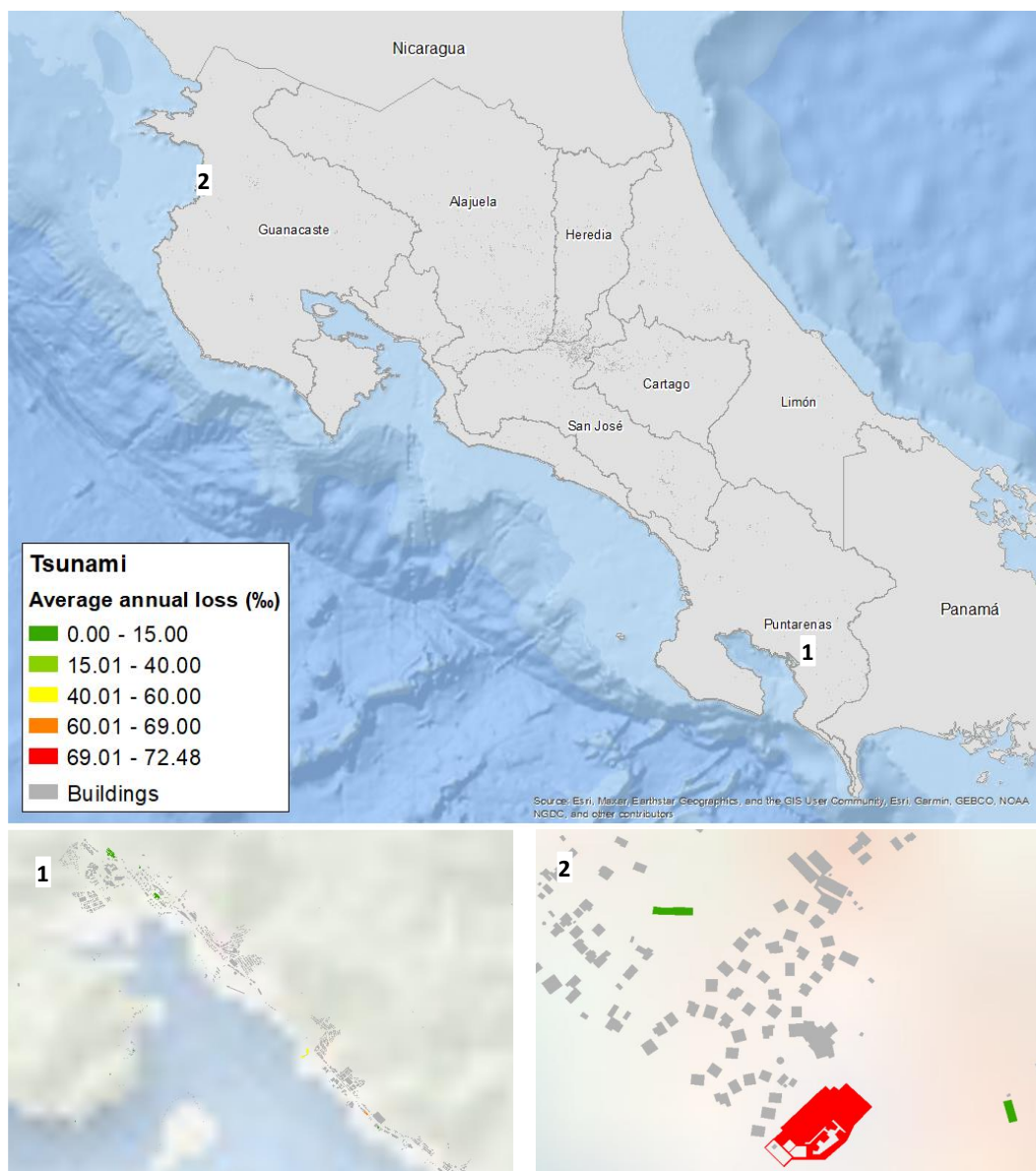


Figure 17. Average Annual Loss from tsunami for hotels represented as polygons. Zoom 1: Golfito. Zoom 2: Nicoya.

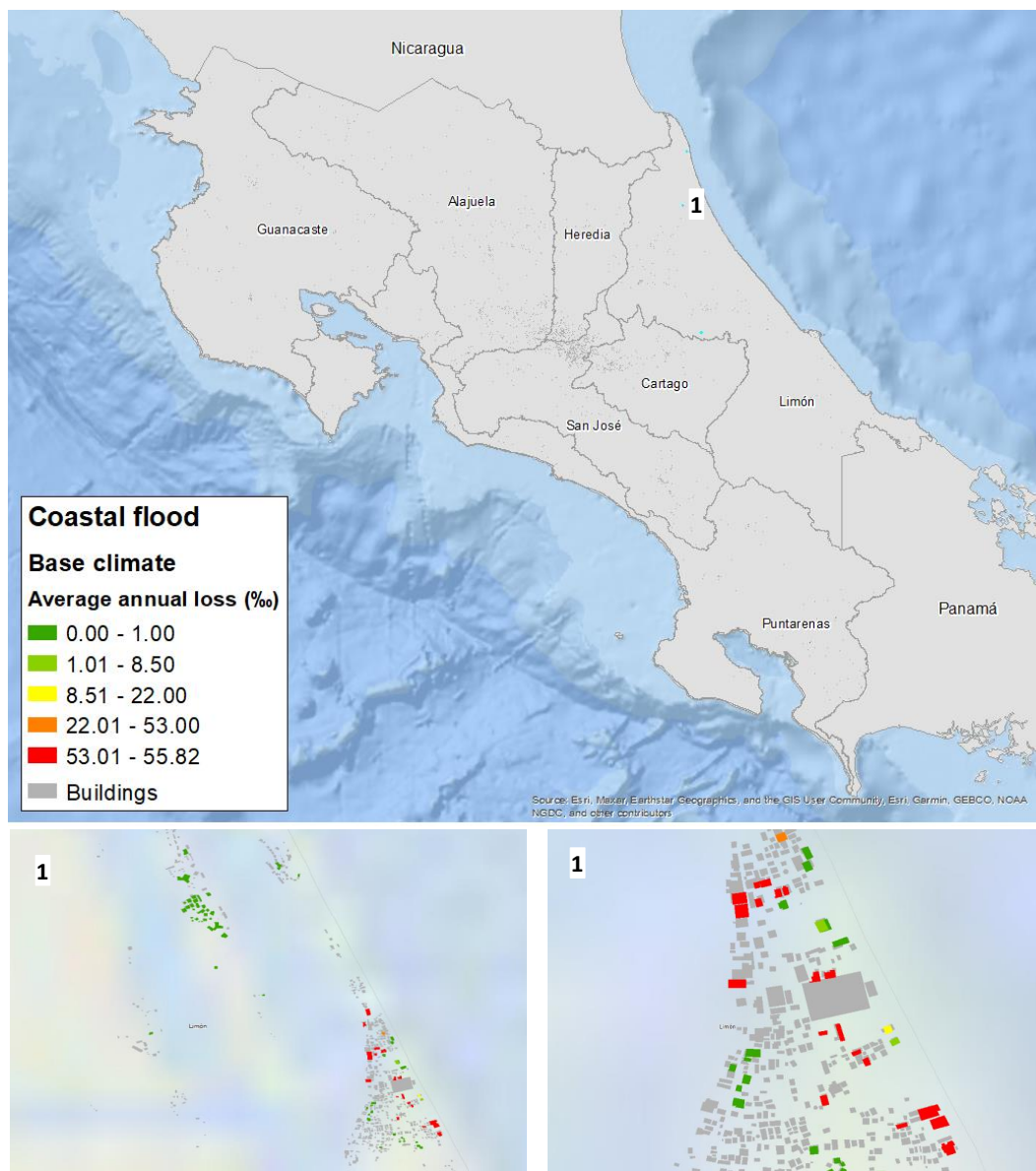


Figure 18. Average Annual Loss from coastal flooding (baseline climate) for hotels represented as polygons. Zoom 1: Pococi.

3.3 Aggregated results by Administrative Units

Risk results are typically presented as portfolio-level and location-specific outputs, as shown previously. However, it is also important to identify which regions of the country concentrate the greatest levels of risk when aggregating results by different administrative geographic units. This approach allows for comparing risk levels across areas with specific administrative jurisdictions, which have clearly defined sectoral or territorial responsibilities within disaster risk management.

The following sections present the total Average Annual Loss (AAL) aggregated across different administrative units. The selected units were chosen to provide insight into the risk levels relevant to various stakeholders in the tourism sector. However, losses can be aggregated by any other unit of interest using the location-based loss file included in the project dataset.

The administrative aggregation units considered in this Deliverable are:

- *Tourism Planning Unit:* These are geographical divisions of Costa Rica used by the Costa Rican Tourism Institute (ICT) to plan and develop tourism in a sectoral manner. Each unit groups together tourism centers, attractions, and infrastructure, serving as the basis for specific development plans. The Tourism Planning Department of ICT is responsible for preparing and updating these plans and providing technical support to local governments.
- *MIDEPLAN regional division:* The Ministry of National Planning and Economic Policy of Costa Rica (MIDEPLAN) organizes the country into six regional planning divisions for development purposes: Central, Chorotega, Brunca, Pacífico Central, Huetar Norte, and Huetar Caribe.
- *Provinces:* Provinces represent the first-level administrative division of the national territory. Costa Rica has seven provinces: San José, Alajuela, Cartago, Heredia, Guanacaste, Puntarenas, and Limón. Each province is subdivided into cantons, which in turn are divided into districts. Costa Rica does not have a “provincial government” in the sense of an independent regional administration.
- *Cantons:* Costa Rica has 84 cantons, each subdivided into districts. Cantons are the most important administrative units for local government in the country. Local government at the cantonal level is administered by Municipalities, which are headed by a Mayor and a Municipal Council elected every four years.

Figure 19 presents the aggregated AAL by tourism planning unit,

Earthquake

Tsunami

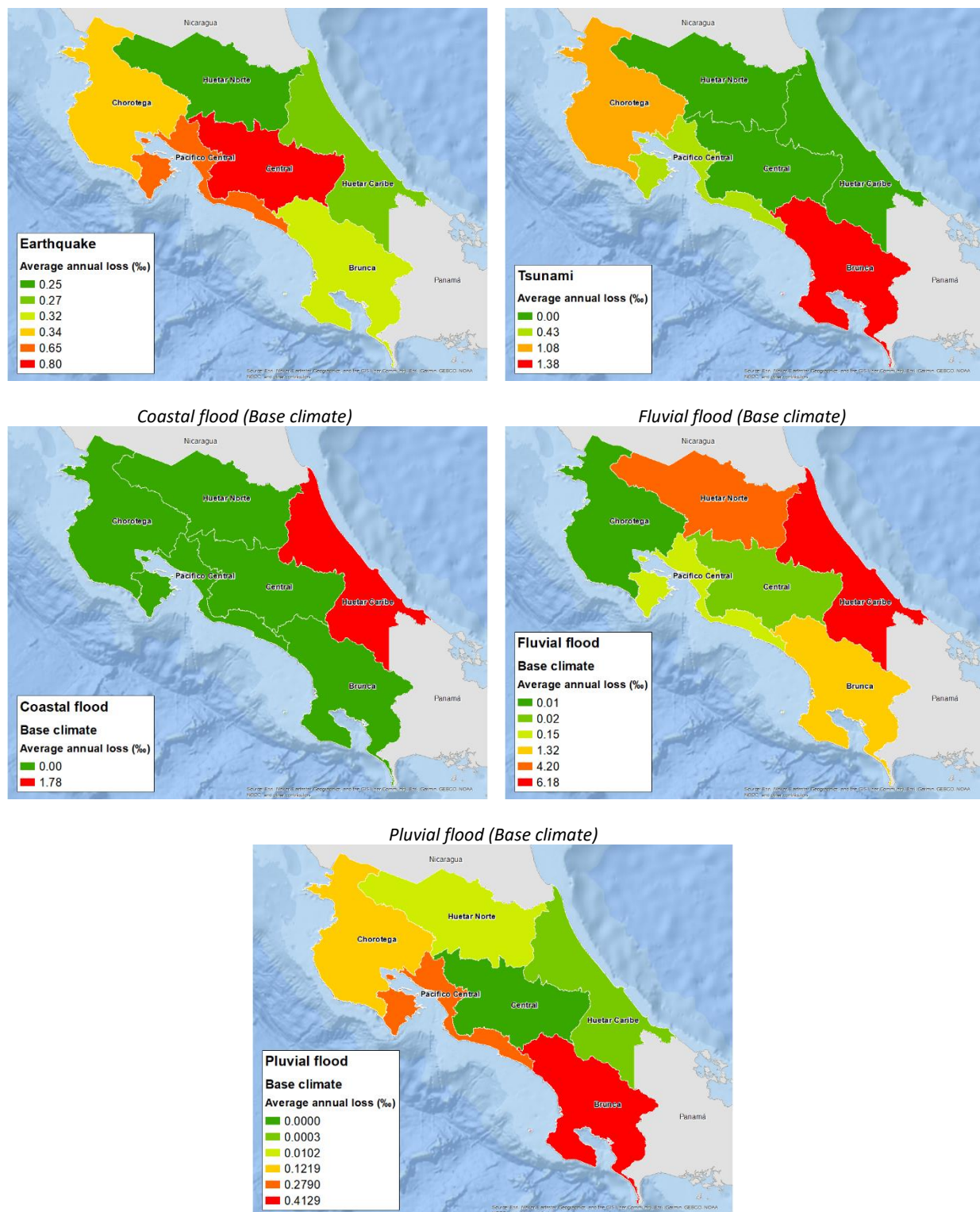


Figure 20 by MIDEPLAN regional division, Figure 21 shows the aggregated AAL by province, and Figure 22 presents the aggregated AAL by canton. In all cases, relative aggregated losses are presented, that is, the aggregated loss normalized by the total exposed value within each administrative unit.

For climate-sensitive hazards, only the baseline climate is shown in the comparison, to avoid overloading the document.

These comparisons enable the prioritization of potential risk management actions to be implemented across the territory, from the perspective of the institutional actor responsible for each specific geographic unit.

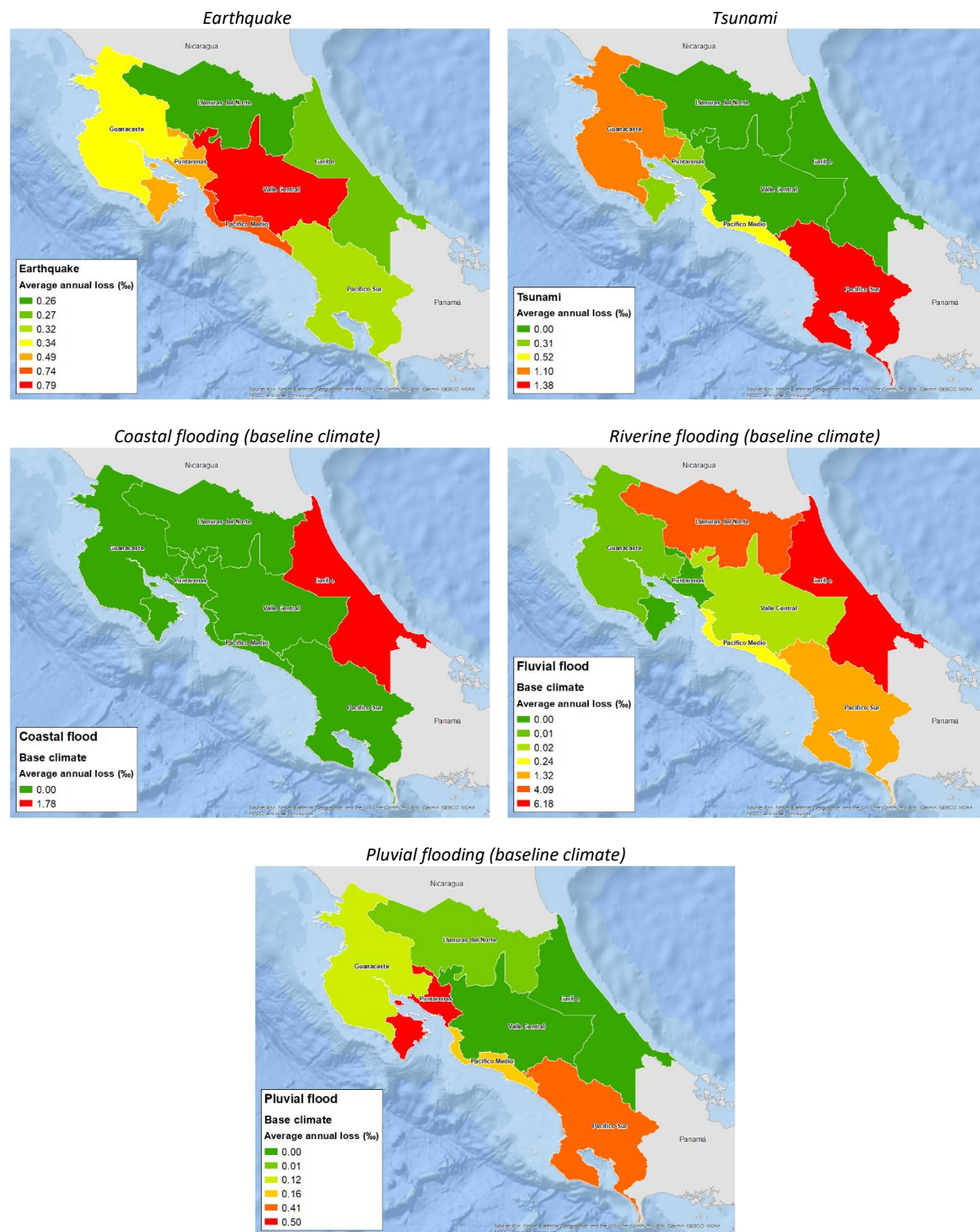


Figure 19. Average Annual Loss for the hazards considered, by tourism planning unit

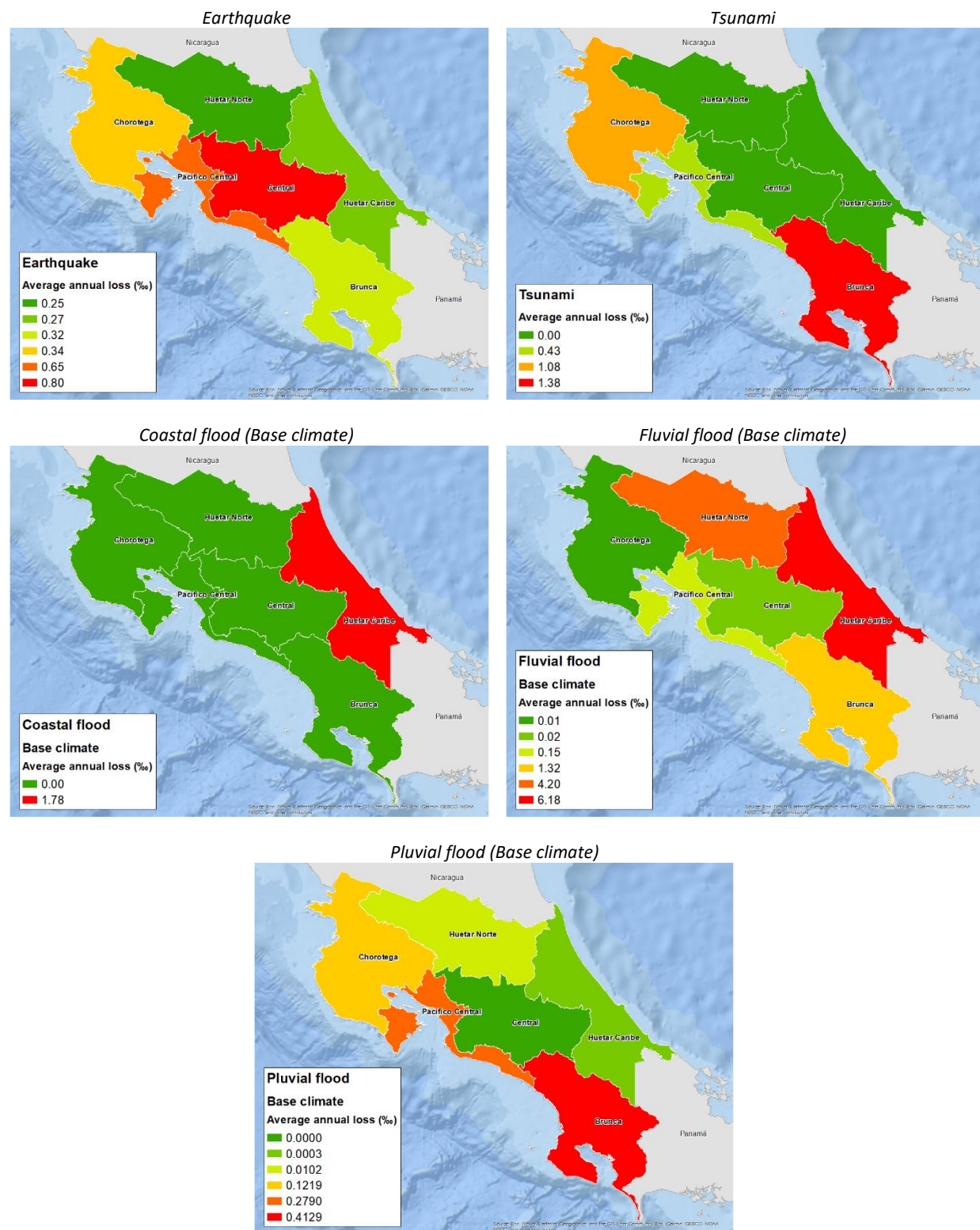


Figure 20. Average Annual Loss for the hazards considered, by MIDEPLAN regional division

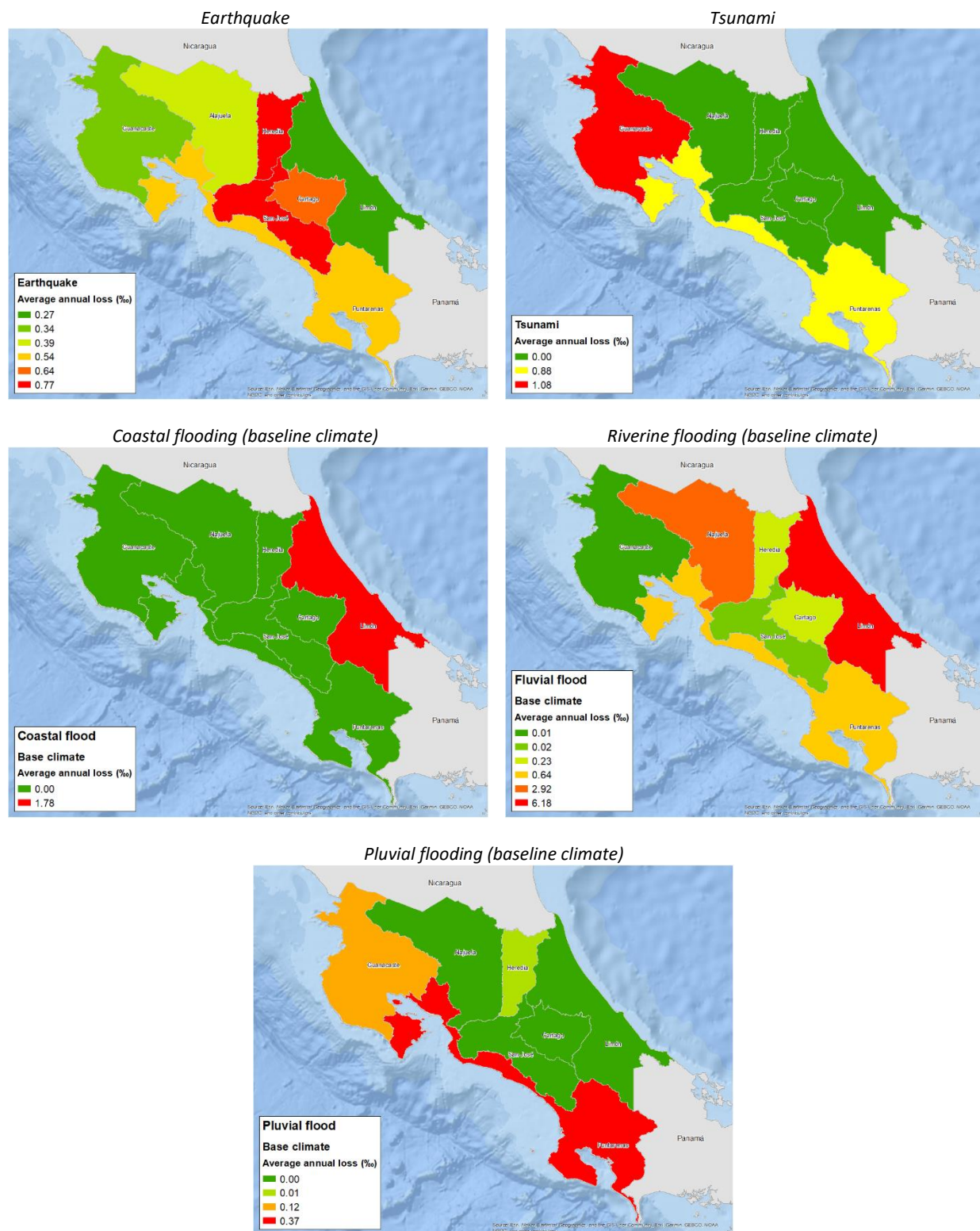


Figure 21. Average Annual Loss for the hazards considered, by province

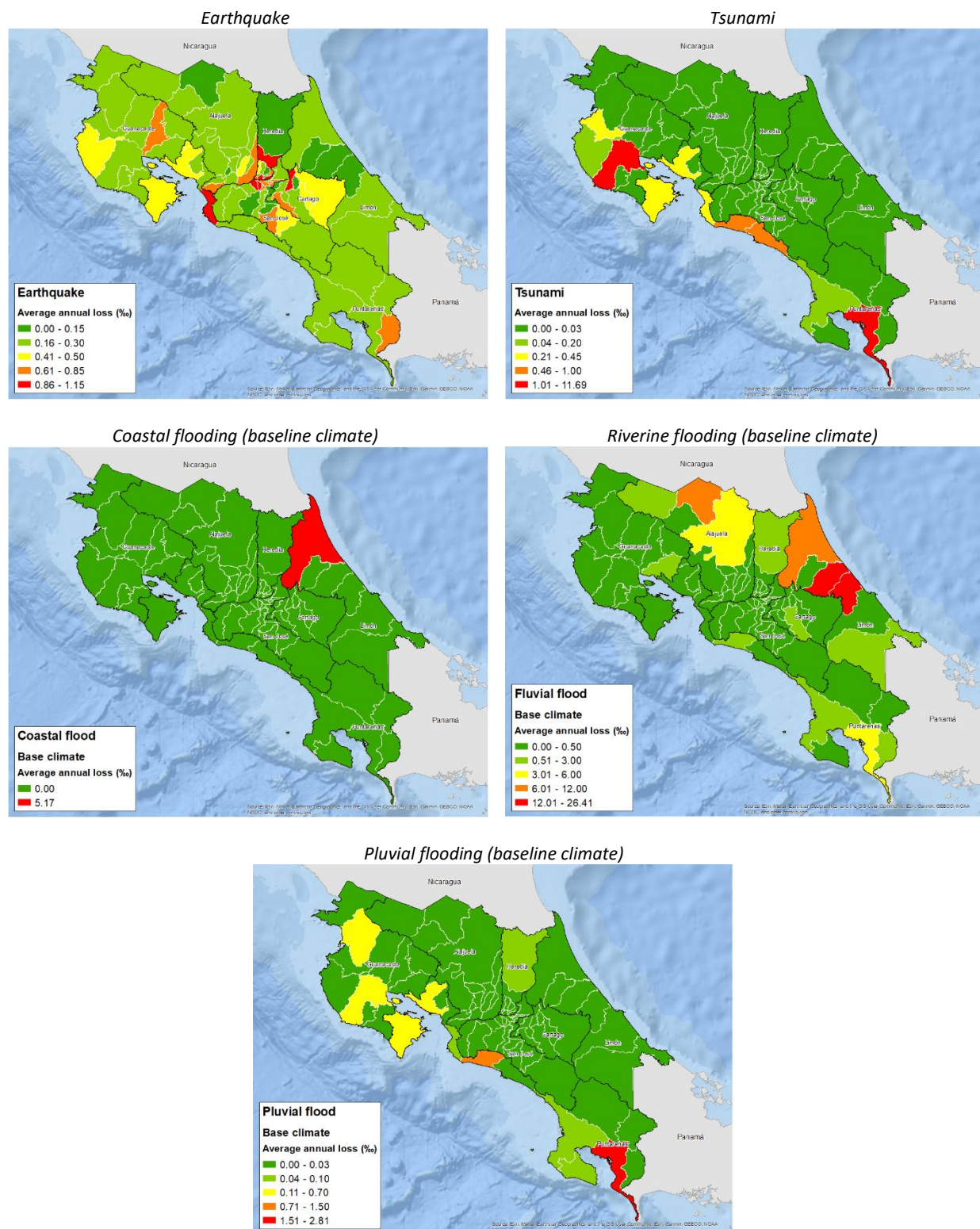


Figure 22. Average Annual Loss for the hazards considered, by canton

4 TRAINING PROGRAM

A comprehensive capacity development program has been designed to fully leverage the modelling work carried out under Operational Project 3, while transferring fundamental knowledge and skills. This training program includes the following groups of activities:

4.1 Workshops and Meetings

The *socialization workshops* are in-person sessions aimed at presenting project progress and partial or final results through plenary sessions. A total of four socialization workshops are planned, two of which have already been held:

- *Workshop 1:* This was the kick-off workshop for the training program activities. The general and specific work plans for the projects were presented, along with the official launch of the training program and the asynchronous virtual course. The Technical Working Groups (TWGs) for each project were also established.
- *Workshop 2:* This workshop presented the overall project progress to all stakeholders, as well as the progress of each of the four projects to the members of the respective Technical Working Groups and other interested actors. The workshop focused on intermediate results from hazard, exposure, and vulnerability modelling. A hands-on exercise on climate modelling was also conducted.
- *Workshop 3:* This workshop focused on the progress of the risk assessment activities, presenting the modelling results for each individual project to the corresponding Technical Working Groups and other stakeholders. It also included a hands-on session on risk metric evaluation and interpretation.
- *Workshop 4:* This is the final closing workshop. It provides a comprehensive summary of activities from all projects and presents the conclusions and recommendations of the assessment. The focus is on the applications and future uses of the modelling results beyond the scope of this consultancy, as well as on the strategies jointly defined with the Technical Working Groups for the sustainability, replicability, and transfer of modelling processes to other territorial entities, regions, or sectors in Costa Rica.

The *working meetings*, in turn, are in-person or virtual sessions (depending on convenience) between the Consultant and the Technical Working Groups (TWGs) to facilitate collaboration on specific tasks and knowledge transfer related to practical aspects such as data collection, management, and processing, as well as the scientific aspects of climate and risk modelling.

Working meetings are arranged individually with each TWG based on participant availability and therefore do not occur simultaneously across all groups, but rather in a sequence or series of meetings over a period of one or two weeks. The specific focus of each meeting depends on the progress of each assessment, although the following general approach is expected for each round of meetings:

- *Round 1 of meetings:* These are the first meetings held with the Technical Working Groups (TWGs) for each project. The project scope is reviewed again, and the necessary agreements are established regarding details of the scope or any value-added components to be implemented in benefit of the project. These discussions aim to promote ownership of results, co-development, and the future sustainability of the modelling processes.
- *Round 2 of meetings:* In this second round, the project progress is reviewed, and specific questions are addressed regarding the modelling of hazards, exposure, and vulnerability. Training sessions are also conducted on the models used in each specific project, complementing the content of the asynchronous virtual course.
- *Round 3 of meetings:* In this third round, the preliminary risk assessment results are reviewed with the TWGs, and final adjustments to the models are jointly agreed upon to consolidate the results. Training sessions on the models used in each project are also provided, further complementing the asynchronous course content.
- *Round 4 of meetings:* The final round of meetings focuses on jointly defining, with the TWGs, the strategies for the future of the modelling work after the completion of the consultancy. The goal is to ensure the long-term sustainability and replicability of the modelling processes in other regions or sectors. These strategies will be defined in the form of a strategic work plan outlining medium-term priorities and needs.

Figure 23 presents the schedule of Workshops and Working Meetings. This schedule should be considered indicative, as it depends on the availability of facilities and the participation of TWG members involved in these activities.

Task	15 Jan 25		Month												15 Apr 25	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Workshops and Working Meetings																
Socialization workshop 1																
Socialization workshop 2																
Socialization workshop 3																
Socialization workshop 4																
Working meeting with TWG 1																
Working meeting with TWG 2																
Working meeting with TWG 3																
Working meeting with TWG 4																

Figure 23. Schedule of workshops and working meetings

4.2 Training Course on Risk Modelling

As part of the capacity-building process related to data use within Operational Project 3 (Assessment of Exposure and Risk for MSME Hotels and Hostels in the Tourism Sector), the Course on Probabilistic Disaster Risk Modelling is being developed.

This course is designed for professionals, specialists, and researchers involved in the Technical Working Group of the GRMA – Costa Rica program, as well as for staff from other interested local institutions, with academic backgrounds in disciplines such as earth sciences, engineering, mathematics, physics, econometrics, or financial/actuarial analysis.

The main objective of the course is to provide participants with the scientific foundations necessary to understand and perform risk modelling, as well as to interpret its results. Upon completion of the training process, participants will be able to carry out risk assessments for natural hazards using the advanced tools of the CAPRA-ROBOT system.

The asynchronous training course officially began on March 18, 2025. It has an approximate duration of 24 weeks, with an estimated time commitment of 2 hours per week. However, the actual duration depends on each participant's level of engagement.

The course covers all modelling topics planned under the GRMA – Costa Rica project, as detailed in the Inception Report (Deliverable 1) of this consultancy. This includes, among others, training activities on seismic hazard and risk, as well as pluvial, riverine, and coastal flood risk.

4.2.1 Module 1 - Fundamentals

The asynchronous course officially began on March 18, 2025, with Module 1, which covered the general foundations of probabilistic risk assessment. Upon completing this module, participants proceeded to Module 2, focused on natural hazard modelling and the evaluation of the vulnerability of exposed elements.

4.2.2 Module 2 – Components of Risk Modelling

Module 2, which started on May 13, 2025, allows each participant to select a hazard of interest among those considered in the GRMA project. The module provides both theoretical and practical materials on hazard and vulnerability modelling for all hazards included in the project, thereby enabling specialized and context-specific training tailored to participants' needs.

Given the scope of this Deliverable, this report presents a summary of the scope and contents of the modules related to earthquake, flooding, and tropical cyclones (the latter being the basis for coastal flood modelling).

4.2.2.1 Earthquake

This module presents the conceptual foundations for the probabilistic assessment of seismic hazard. It covers the basic principles of seismology, characterization of strong ground motion, methodology for seismic hazard assessment, and the response of soils during a seismic event.

Regarding exposure, the module addresses the minimum requirements for constructing an exposure database, including geolocation, characterization, and economic valuation of assets.

In addition, the module covers the analysis of physical vulnerability, which must be evaluated and assigned to each exposed component.

Table 4 presents the topics covered in each unit in detail.

Table 4. Syllabus for module 2: Earthquake

Unit	Title	Topics
1	Basic Aspects of Seismology	• Plate tectonics • Geological faults • Seismic source model • Seismic moment and magnitude • Slip distribution and seismic moment release • Seismic waves • Focal mechanism
2	Strong Ground Motion	• Accelerograms • Source spectrum • Random vibrations • Attenuation models • Structural response
3	Probabilistic Seismic Hazard Assessment	• Seismogenic sources • Seismicity • Attenuation • Stochastic catalogue • Hazard integration • Deterministic assessment
4	Site Effects	• Definition of site effects • Estimation techniques • 1D elastic response • 1D nonlinear response • Regional site effects
5	Damage Models: Fragility and Vulnerability Functions	• Fragility curves • Vulnerability curves
6	Seismic Vulnerability	• Structural behavior under cyclic lateral loads • Behavior of masonry structures • Behavior of concrete structures

The theoretical sessions are complemented by hands-on practical sessions, in which participants learn to use specialized software tools for seismic hazard modelling, including the following:

Strong Motion Analyst (SMA): A program for processing seismological information. It implements methodologies for seismic signal processing, site response analysis, strong ground motion attenuation, and seismological catalogue processing.

R-CRISIS: The seismic hazard module of CAPRA-ROBOT, developed primarily by Mario Ordaz (UNAM, Mexico). It is a versatile tool that allows for Probabilistic Seismic Hazard Analysis (PSHA) and has been used worldwide in applications such as the nuclear industry, insurance sector, building codes, and seismic microzonation studies.

Vulnerability Studio: A tool used to model the vulnerability of exposed elements through mathematical functions that relate hazard intensity to direct physical impact. It implements several methods for developing vulnerability functions adapted to different types of hazards, allowing the estimation of loss probability functions for various intensity levels.

CAPRA-ROBOT: The risk calculation engine. It computes the Loss Exceedance Curve (LEC) for any exposure database, using the probabilistic CAT-type risk assessment framework. This module aggregates losses from multiple hazards, generating multi-hazard risk results. CAPRA-ROBOT also calculates financial risk metrics such as Expected Annual Loss (AAL) and Probable Maximum Loss (PML), among others.

Through these tools, participants will be able to perform probabilistic seismic hazard modelling and risk estimation, fully aligned with the CAPRA methodology applied in the GRMA project. These skills directly support the objectives of Operational Project 3, by strengthening the integration of technical tools into disaster risk management for the tourism sector.

4.2.2.2 Tropical Cyclones

This module begins by covering the methods required to incorporate climate change into hydrometeorological risk assessments. It then introduces key meteorological concepts related to the formation of tropical depressions, storms, and cyclones, their life cycle, wind field and storm surge models, as well as the main modelling approaches used to represent these phenomena.

From an engineering perspective, the module also includes topics such as topographic effects, gust duration transformations, building response, and structural damage models.

Regarding exposure, the module addresses the minimum requirements for building an exposure database, including geolocation, asset characterization, and economic valuation.

Additionally, the module introduces the mathematical models necessary for the correct application and understanding of probabilistic risk assessment theory, along with the associated results and metrics.

Table 5 presents in detail the topics covered in each unit.

Table 5. Syllabus for module 2: Tropical cyclones

Unit	Title	Topics
1	Basic Concepts of Climate Change	• The Earth's climate system • Energy balance • General atmospheric circulation • Radiative forcing • Greenhouse gas emissions • Global circulation models (GCMs) • Global projections
2	Structure and Formation of Tropical Cyclones	• Structure • Formation conditions • Generation of tropical cyclones • Saffir–Simpson scale • Tracks and warnings
3	Effects of Tropical Cyclones	• Gradient wind • Boundary layer • Gust velocity • Tide hydrographs • Ekman spiral • Low-pressure storm surge
4	Probabilistic Assessment of Tropical Cyclone Hazard	• Track completeness • Track perturbation • Cyclone catalogue and hazard integration

		• Influence of climate change on cyclone formation • Sea level rise trends
5	Damage Models: Fragility and Vulnerability Functions	• Fragility curves • Vulnerability curves
6	Wind and Flood Vulnerability	• Wind effects on structures • Pressure loads on buildings • Cyclic wind loads on tall buildings • Vulnerability to wind fields • Vulnerability to debris impact • Vulnerability to storm surge flooding

The theoretical sessions are complemented by hands-on practical sessions, where participants learn to use specialized software tools for tropical cyclone hazard modelling, including the following:

Tropical Cyclones Hazard Modeler (TCHM): This is the CAPRA-ROBOT platform module for tropical cyclone hazard modelling. It implements calculation methodologies for strong winds, storm surge, and accumulated precipitation. TCHM allows realistic simulation of the intensification and weakening of tropical cyclones as they move along stochastic tracks, as well as their surface-level impacts in terms of hazard intensity.

Vulnerability Studio: A tool used to model the vulnerability of exposed elements through mathematical functions that relate hazard intensity to direct physical impact. It includes several methods for developing vulnerability functions tailored to different types of hazards, allowing the estimation of loss probability functions for various intensity levels.

CAPRA-ROBOT: The risk calculation engine. It computes the Loss Exceedance Curve (LEC) for any exposure database using the probabilistic CAT-type risk assessment framework. This module aggregates losses from different hazards to generate multi-hazard risk results. CAPRA-ROBOT also calculates financial risk metrics, such as the Expected Annual Loss (AAL) and the Probable Maximum Loss (PML), among others.

Through these tools, participants gain the ability to perform probabilistic tropical cyclone hazard modelling and risk estimation, fully aligned with the CAPRA methodology applied in the GRMA project. These capabilities directly support the objectives of Operational Project 3, strengthening the integration of technical tools into disaster risk management for the tourism sector.

4.2.2.3 Floods

This module begins by covering the methods required to incorporate climate change into hydrometeorological risk assessments, given that phenomena such as rainfall are significantly affected by climate change.

It then addresses key aspects of riverine flooding, which occurs when excessive rainfall over a prolonged period causes a river to exceed its capacity, leading to overflow of the river channel and inundation of surrounding areas, depending on local topography.

A climate generator is used to produce precipitation series consistent with the historical rainfall regime of the study area.

From an engineering perspective, the module analyzes the stochastic series of intense precipitation events and the identification of extreme rainfall events that may trigger flooding. It also includes complete hydrological and hydraulic analyses at both the basin and river channel levels.

Regarding exposure, the module discusses the minimum requirements for building an exposure database, including geolocation, asset characterization, and economic valuation.

Additionally, the module presents the mathematical models required for the proper application and understanding of probabilistic risk assessment theory, along with its results and associated metrics.

Table 6 provides a detailed overview of the topics covered in each unit.

Table 6. Syllabus for module 2: Floods

Unit	Title	Topics
1	Basic Concepts of Climate Change	• The Earth's climate system • Energy balance • General atmospheric circulation • Radiative forcing • Greenhouse gas emissions • Global circulation models (GCMs) • Global projections
2	Incorporating Climate Change into Hazard and Risk Modelling	• Downscaling • Stochastic simulation • Scaling rule • All-variations model
3	Hydrological Modelling	• Hydrological cycle • Reynolds transport theorem • Hydrological system: precipitation, evapotranspiration, infiltration, and runoff • Watershed outflow hydrograph
4	Hydraulic Modelling	• One-dimensional modelling • Two-dimensional modelling • HEC-RAS
5	Damage Models: Fragility and Vulnerability Functions	• Fragility curves • Vulnerability curves • Binary vulnerability
6	Flood Vulnerability	• Rainfall-landslide thresholds • Rainfall-induced landslides • Earthquake-induced landslides

The theoretical sessions are complemented by hands-on practical sessions, where participants learn to use specialized software tools for flood hazard modelling, including the following:

Drought Pro: An advanced simulation tool that enables the stochastic modelling of meteorological forcing, particularly rainfall, as a triggering factor for landslides. Although originally designed for drought modelling (hence its name), it has evolved into a general climate simulation system. Using a stochastic climate generator, it produces multiple simulations of meteorological variables (such as precipitation and temperature) based on available historical daily series for the region. Given these capabilities, Drought Pro is applied to the probabilistic modelling of various phenomena, including droughts, floods, landslides, and wildfires, by constructing probabilistic models of meteorological forcing.

Flood Analyst: A software tool designed for flood hazard assessment. It estimates hazard intensities for heavy rainfall and riverine flooding events across multiple locations within the study area. Flood Analyst generates stochastic heavy rainfall events and is coupled with HEC-RAS (Brunner & Bonner, 1994), which performs the hydrological and hydraulic analyses for each event and provides the corresponding flood footprint.

Vulnerability Studio: A tool for modelling the vulnerability of exposed assets through mathematical functions that relate hazard intensity to direct physical impact. It incorporates multiple methods for developing vulnerability functions tailored to specific hazard types, enabling the estimation of loss probability functions for various intensity levels.

CAPRA-ROBOT: As previously described, this is the risk computation engine. It calculates the Loss Exceedance Curve (LEC) for any exposure database using a probabilistic CAT-type risk assessment framework. This module aggregates losses from different hazards to generate multi-hazard risk results and computes financial risk metrics such as the Expected Annual Loss (AAL) and the Probable Maximum Loss (PML), among others.

Upon completion, participants will be able to perform probabilistic flood hazard modelling and risk estimation using these tools, all of which are aligned with the CAPRA methodology applied in the GRMA project. These capabilities support the objectives of Operational Project 3, enhancing the integration of technical tools into disaster risk management within the tourism sector.

4.2.3 Module 3 – Advanced Applications

Once participants successfully complete Module 2, they may continue with Module 3, which focuses on advanced applications in risk management and climate change adaptation. This module, which began on October 15, represents the final stage of the course and is essential for achieving a comprehensive understanding of the full modelling and decision-making process.

While completing all three modules is recommended for full professional training experience, participants interested only in understanding the general structure of the risk management process and its strategic relevance had the option to move directly from Module 1 to Module 3.

This module addresses key topics for decision-making in contexts of high uncertainty and complex systems, such as resilience modelling in dynamic systems, holistic risk assessment, robust decision-making, risk control engineering, and an introduction to financial protection against disasters.

Table 7 provides a detailed overview of the topics covered in each unit. This module is particularly valuable as it offers advanced tools to integrate technical risk analysis with planning, investment, and public policy processes, supporting a comprehensive approach to disaster risk management and climate adaptation.

Table 7. Syllabus for module 3: Advanced applications

Unit	Title	Topics
1	Modelling the Resilience of Infrastructure Systems	• Concept of systems • Interdependence of elements • Supply–demand imbalance • Performance curves • Performance simulation
2	Holistic Risk Assessment	• Definition of contextual conditions • Social fragility and lack of resilience • Aggravation coefficient • Indicator systems and membership functions • Disaggregation of holistic indicators
3	Robust Decision-Making	• Deep uncertainty • Uncertain future states • Random set theory • Imprecise risk metrics • Decision-making under deep uncertainty
4	Risk Control Engineering	• Risk control process • Formulation of intervention actions • Stochastic optimization • Investment curves • Optimal risk management and adaptation plans
5	Introduction to Financial Protection	• Types of financial instruments • Rationale and costs of instruments • Risk retention and transfer structures • Insurance claims mechanisms • Introduction to CAT Bonds

4.2.4 Enrolled Participants in the Course

Below is a list of participants enrolled in the course who are associated with Operational Project 3. It is important to note that participants may register for more than one hazard module, depending on their professional interests and areas of focus.

Participant	Institutions	Enrolled modules
Manfred Canales	Futurismo	Module 1, Module 3
Jorge Masis	GIZ (Futurismo)	Module 1, Module 2: Landslides, Floods, Drought, Module 3
Nicolás Morales	GIZ (Futurismo)	Module 1, Module 2: Tropical Cyclones, Landslides, Floods, Drought, Module 3
Víctor Salazar	Aseguradora Sagicor	Module 1, Module 2: Earthquakes, Volcanoes, Module 3

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A.1 PROBABLE MAXIMUM LOSS (PML) BY HAZARD AND CLIMATE SCENARIO

This table presents the absolute (CRC million) and relative (%) PML values for all hazards and climate scenarios considered, across several return periods. For riverine and pluvial flood hazards, the **maximum** and **minimum** PML values are highlighted in **red** and **green**, respectively.

Hazard	Climate	Absolute PML (CRC)									Relative PML (%)								
		10	25	50	100	250	500	1000	2500	5000	10	25	50	100	250	500	1000	2500	5000
Earthquake		1,415	3,539	7,077	14,154	26,914	34,607	44,098	60,125	75,562	0.082	0.205	0.411	0.821	1.562	2.008	2.559	3.489	4.385
Tsunami		1,463	3,656	6,970	9,031	12,374	15,465	19,135	25,059	30,521	0.085	0.212	0.404	0.524	0.718	0.897	1.110	1.454	1.771
Coastal flooding	Base climate	483	992	1,462	2,119	3,394	4,799	6,745	10,511	14,654	0.028	0.058	0.085	0.123	0.197	0.278	0.391	0.610	0.850
	HRMIP-SSP5-50	313	617	1,009	1,631	3,041	4,847	7,703	14,168	22,436	0.018	0.036	0.059	0.095	0.176	0.281	0.447	0.822	1.302
Riverine flooding	Base	3,763	8,112	11,345	12,323	12,940	13,587	14,266	14,979	15,728	0.218	0.471	0.658	0.715	0.751	0.788	0.828	0.869	0.913
	EC-SSP1-35	3,699	7,975	11,153	12,115	12,721	13,357	14,025	14,726	15,462	0.215	0.463	0.647	0.703	0.738	0.775	0.814	0.855	0.897
	EC-SSP1-50	3,665	7,900	11,049	12,002	12,602	13,232	13,894	14,588	15,318	0.213	0.458	0.641	0.696	0.731	0.768	0.806	0.847	0.889
	EC-SSP1-100	3,633	7,832	10,954	11,899	12,494	13,118	13,774	14,463	15,186	0.211	0.454	0.636	0.690	0.725	0.761	0.799	0.839	0.881
	EC-SSP2-35	3,576	7,708	10,781	11,711	12,296	12,911	13,556	14,234	14,946	0.207	0.447	0.626	0.680	0.714	0.749	0.787	0.826	0.867
	EC-SSP2-50	3,611	7,785	10,888	11,827	12,418	13,039	13,691	14,376	15,095	0.210	0.452	0.632	0.686	0.721	0.757	0.794	0.834	0.876
	EC-SSP2-100	3,509	7,565	10,580	11,493	12,068	12,671	13,305	13,970	14,668	0.204	0.439	0.614	0.667	0.700	0.735	0.772	0.811	0.851
	EC-SSP3-35	3,575	7,706	10,777	11,706	12,292	12,906	13,552	14,229	14,941	0.207	0.447	0.625	0.679	0.713	0.749	0.786	0.826	0.867
	EC-SSP3-50	3,497	7,539	10,543	11,453	12,025	12,626	13,258	13,921	14,617	0.203	0.437	0.612	0.665	0.698	0.733	0.769	0.808	0.848
	EC-SSP3-100	3,381	7,288	10,193	11,072	11,626	12,207	12,817	13,458	14,131	0.196	0.423	0.591	0.642	0.675	0.708	0.744	0.781	0.820
	EC-SSP5-35	3,585	7,727	10,807	11,739	12,326	12,943	13,590	14,269	14,983	0.208	0.448	0.627	0.681	0.715	0.751	0.789	0.828	0.869
	EC-SSP5-50	3,520	7,587	10,611	11,527	12,103	12,708	13,343	14,011	14,711	0.204	0.440	0.616	0.669	0.702	0.737	0.774	0.813	0.854
	EC-SSP5-100	3,291	7,095	9,922	10,778	11,317	11,883	12,477	13,101	13,756	0.191	0.412	0.576	0.625	0.657	0.690	0.724	0.760	0.798
	GFDL-SSP1-35	3,810	8,214	11,487	12,478	13,102	13,757	14,445	15,167	15,926	0.221	0.477	0.667	0.724	0.760	0.798	0.838	0.880	0.924
	GFDL-SSP1-50	3,728	8,037	11,241	12,210	12,821	13,462	14,135	14,842	15,584	0.216	0.466	0.652	0.709	0.744	0.781	0.820	0.861	0.904
	GFDL-SSP1-100	3,806	8,206	11,476	12,466	13,089	13,743	14,431	15,152	15,910	0.221	0.476	0.666	0.723	0.760	0.797	0.837	0.879	0.923
	GFDL-SSP2-35	3,712	8,002	11,191	12,156	12,764	13,402	14,072	14,776	15,515	0.215	0.464	0.649	0.705	0.741	0.778	0.817	0.857	0.900
	GFDL-SSP2-50	3,688	7,950	11,118	12,078	12,681	13,316	13,981	14,680	15,414	0.214	0.461	0.645	0.701	0.736	0.773	0.811	0.852	0.894
	GFDL-SSP2-100	3,642	7,852	10,981	11,929	12,525	13,151	13,809	14,499	15,224	0.211	0.456	0.637	0.692	0.727	0.763	0.801	0.841	0.883
	GFDL-SSP3-35	3,662	7,894	11,040	11,993	12,592	13,222	13,883	14,577	15,306	0.212	0.458	0.641	0.696	0.731	0.767	0.806	0.846	0.888
	GFDL-SSP3-50	3,534	7,619	10,655	11,574	12,153	12,760	13,398	14,068	14,772	0.205	0.442	0.618	0.672	0.705	0.740	0.777	0.816	0.857
	GFDL-SSP3-100	3,338	7,196	10,065	10,933	11,479	12,053	12,656	13,289	13,953	0.194	0.418	0.584	0.634	0.666	0.699	0.734	0.771	0.810
	GFDL-SSP5-35	3,682	7,937	11,100	12,058	12,661	13,294	13,958	14,656	15,389	0.214	0.461	0.644	0.700	0.735	0.771	0.810	0.850	0.893
	GFDL-SSP5-50	3,563	7,681	10,742	11,668	12,252	12,864	13,508	14,183	14,892	0.207	0.446	0.623	0.677	0.711	0.746	0.784	0.823	0.864
	GFDL-SSP5-100	3,257	7,020	9,818	10,665	11,198	11,758	12,346	12,963	13,612	0.189	0.407	0.570	0.619	0.650	0.682	0.716	0.752	0.790
		MPI-SSP1-35	4,043	8,716	12,189	13,241	13,903	14,598	15,328	16,094	16,899	0.235	0.506	0.707	0.768	0.807	0.847	0.889	0.934

Hazard	Climate	Absolute PML (CRC)									Relative PML (%)								
		10	25	50	100	250	500	1000	2500	5000	10	25	50	100	250	500	1000	2500	5000
	MPI-SSP1-50	4,055	8,741	12,224	13,279	13,943	14,640	15,372	16,140	16,947	0.235	0.507	0.709	0.771	0.809	0.850	0.892	0.937	0.983
	MPI-SSP1-100	4,318	9,308	13,018	14,141	14,848	15,590	16,370	17,188	18,047	0.251	0.540	0.755	0.821	0.862	0.905	0.950	0.997	1.047
	MPI-SSP2-35	4,246	9,152	12,800	13,904	14,599	15,329	16,096	16,900	17,745	0.246	0.531	0.743	0.807	0.847	0.890	0.934	0.981	1.030
	MPI-SSP2-50	4,594	9,903	13,850	15,045	15,797	16,587	17,417	18,288	19,202	0.267	0.575	0.804	0.873	0.917	0.963	1.011	1.061	1.114
	MPI-SSP2-100	4,010	8,643	12,088	13,131	13,787	14,477	15,201	15,961	16,759	0.233	0.502	0.701	0.762	0.800	0.840	0.882	0.926	0.972
	MPI-SSP3-35	4,114	8,869	12,404	13,474	14,148	14,855	15,598	16,378	17,197	0.239	0.515	0.720	0.782	0.821	0.862	0.905	0.950	0.998
	MPI-SSP3-50	4,449	9,590	13,412	14,569	15,297	16,062	16,865	17,709	18,594	0.258	0.556	0.778	0.845	0.888	0.932	0.979	1.028	1.079
	MPI-SSP3-100	3,990	8,601	12,029	13,066	13,720	14,406	15,126	15,882	16,676	0.232	0.499	0.698	0.758	0.796	0.836	0.878	0.922	0.968
	MPI-SSP5-35	3,978	8,575	11,992	13,027	13,678	14,362	15,080	15,834	16,626	0.231	0.498	0.696	0.756	0.794	0.833	0.875	0.919	0.965
	MPI-SSP5-50	3,852	8,305	11,614	12,616	13,247	13,909	14,605	15,335	16,102	0.224	0.482	0.674	0.732	0.769	0.807	0.847	0.890	0.934
	MPI-SSP5-100	4,294	9,257	12,946	14,063	14,766	15,505	16,280	17,094	17,949	0.249	0.537	0.751	0.816	0.857	0.900	0.945	0.992	1.042
Pluvial flooding	Base	461	993	1,388	1,508	1,553	1,600	1,648	1,697	1,748	0.027	0.058	0.081	0.088	0.090	0.093	0.096	0.098	0.101
	EC-SSP1-35	463	999	1,397	1,518	1,563	1,610	1,659	1,708	1,760	0.027	0.058	0.081	0.088	0.091	0.093	0.096	0.099	0.102
	EC-SSP1-50	452	974	1,362	1,479	1,524	1,570	1,617	1,665	1,715	0.026	0.057	0.079	0.086	0.088	0.091	0.094	0.097	0.100
	EC-SSP1-100	455	980	1,371	1,489	1,534	1,580	1,627	1,676	1,727	0.026	0.057	0.080	0.086	0.089	0.092	0.094	0.097	0.100
	EC-SSP2-35	444	958	1,340	1,455	1,499	1,544	1,590	1,638	1,687	0.026	0.056	0.078	0.084	0.087	0.090	0.092	0.095	0.098
	EC-SSP2-50	452	975	1,363	1,480	1,525	1,571	1,618	1,666	1,716	0.026	0.057	0.079	0.086	0.088	0.091	0.094	0.097	0.100
	EC-SSP2-100	426	919	1,286	1,397	1,438	1,482	1,526	1,572	1,619	0.025	0.053	0.075	0.081	0.083	0.086	0.089	0.091	0.094
	EC-SSP3-35	440	948	1,326	1,441	1,484	1,528	1,574	1,621	1,670	0.026	0.055	0.077	0.084	0.086	0.089	0.091	0.094	0.097
	EC-SSP3-50	437	943	1,319	1,433	1,476	1,520	1,566	1,613	1,661	0.025	0.055	0.077	0.083	0.086	0.088	0.091	0.094	0.096
Pluvial flooding	EC-SSP3-100	402	867	1,212	1,317	1,356	1,397	1,439	1,482	1,527	0.023	0.050	0.070	0.076	0.079	0.081	0.083	0.086	0.089
	EC-SSP5-35	449	968	1,354	1,471	1,515	1,560	1,607	1,655	1,705	0.026	0.056	0.079	0.085	0.088	0.091	0.093	0.096	0.099
	EC-SSP5-50	438	944	1,320	1,434	1,477	1,521	1,567	1,614	1,662	0.025	0.055	0.077	0.083	0.086	0.088	0.091	0.094	0.096
	EC-SSP5-100	389	838	1,172	1,273	1,311	1,351	1,391	1,433	1,476	0.023	0.049	0.068	0.074	0.076	0.078	0.081	0.083	0.086
	GFDL-SSP1-35	465	1,001	1,400	1,521	1,567	1,614	1,662	1,712	1,764	0.027	0.058	0.081	0.088	0.091	0.094	0.096	0.099	0.102
	GFDL-SSP1-50	457	986	1,379	1,498	1,543	1,589	1,636	1,686	1,736	0.027	0.057	0.080	0.087	0.090	0.092	0.095	0.098	0.101
	GFDL-SSP1-100	457	985	1,378	1,496	1,541	1,588	1,635	1,684	1,735	0.027	0.057	0.080	0.087	0.089	0.092	0.095	0.098	0.101
	GFDL-SSP2-35	450	969	1,356	1,472	1,517	1,562	1,609	1,657	1,707	0.026	0.056	0.079	0.085	0.088	0.091	0.093	0.096	0.099
	GFDL-SSP2-50	443	956	1,337	1,452	1,496	1,541	1,587	1,635	1,684	0.026	0.055	0.078	0.084	0.087	0.089	0.092	0.095	0.098
	GFDL-SSP2-100	444	957	1,339	1,454	1,498	1,543	1,589	1,637	1,686	0.026	0.056	0.078	0.084	0.087	0.090	0.092	0.095	0.098
	GFDL-SSP3-35	447	964	1,348	1,465	1,508	1,554	1,600	1,648	1,698	0.026	0.056	0.078	0.085	0.088	0.090	0.093	0.096	0.099
	GFDL-SSP3-50	426	917	1,283	1,394	1,436	1,479	1,523	1,569	1,616	0.025	0.053	0.074	0.081	0.083	0.086	0.088	0.091	0.094
	GFDL-SSP3-100	389	838	1,172	1,273	1,312	1,351	1,392	1,433	1,476	0.023	0.049	0.068	0.074	0.076	0.078	0.081	0.083	0.086
	GFDL-SSP5-35	447	963	1,347	1,463	1,507	1,552	1,599	1,647	1,696	0.026	0.056	0.078	0.085	0.087	0.090	0.093	0.096	0.098
	GFDL-SSP5-50	430	926	1,295	1,407	1,449	1,493	1,537	1,584	1,631	0.025	0.054	0.075	0.082	0.084	0.087	0.089	0.092	0.095
	GFDL-SSP5-100	380	818	1,145	1,243	1,281	1,319	1,359	1,399	1,441	0.022	0.047	0.066	0.072	0.074	0.077	0.079	0.081	0.084
	MPI-SSP1-35	488	1,052	1,471	1,598	1,646	1,695	1,746	1,798	1,852	0.028	0.061	0.085	0.093	0.095	0.098	0.101	0.104	0.107
	MPI-SSP1-50	487	1,051	1,469	1,596	1,644	1,693	1,744	1,796	1,850	0.028	0.061	0.085	0.093	0.095	0.098	0.101	0.104	0.107

Hazard	Climate	Absolute PML (CRC)									Relative PML (%)								
		10	25	50	100	250	500	1000	2500	5000	10	25	50	100	250	500	1000	2500	5000
	MPI-SSP1-100	516	1,112	1,556	1,690	1,741	1,793	1,847	1,902	1,959	0.030	0.065	0.090	0.098	0.101	0.104	0.107	0.110	0.114
	MPI-SSP2-35	506	1,091	1,526	1,657	1,707	1,758	1,811	1,865	1,921	0.029	0.063	0.089	0.096	0.099	0.102	0.105	0.108	0.111
	MPI-SSP2-50	543	1,171	1,637	1,778	1,832	1,887	1,943	2,002	2,062	0.032	0.068	0.095	0.103	0.106	0.109	0.113	0.116	0.120
	MPI-SSP2-100	482	1,039	1,453	1,579	1,626	1,675	1,725	1,777	1,830	0.028	0.060	0.084	0.092	0.094	0.097	0.100	0.103	0.106
	MPI-SSP3-35	493	1,063	1,487	1,615	1,663	1,713	1,765	1,818	1,872	0.029	0.062	0.086	0.094	0.097	0.099	0.102	0.105	0.109
	MPI-SSP3-50	526	1,135	1,587	1,724	1,776	1,829	1,884	1,940	1,999	0.031	0.066	0.092	0.100	0.103	0.106	0.109	0.113	0.116
	MPI-SSP3-100	479	1,033	1,445	1,570	1,617	1,666	1,716	1,767	1,820	0.028	0.060	0.084	0.091	0.094	0.097	0.100	0.103	0.106
	MPI-SSP5-35	479	1,032	1,443	1,567	1,614	1,663	1,713	1,764	1,817	0.028	0.060	0.084	0.091	0.094	0.096	0.099	0.102	0.105
	MPI-SSP5-50	465	1,002	1,402	1,523	1,569	1,616	1,664	1,714	1,765	0.027	0.058	0.081	0.088	0.091	0.094	0.097	0.099	0.102
	MPI-SSP5-100	510	1,100	1,539	1,671	1,721	1,773	1,826	1,881	1,937	0.030	0.064	0.089	0.097	0.100	0.103	0.106	0.109	0.112

A.2 DATASET OF RISK ASSESSMENT PRODUCTS FOR TOURISM

As part of the products included in this deliverable, a web repository (Drive) was established to host the risk results of the Tourism project. This repository compiles deliverables 8c, 8d, 8e.

Below is a list of the files that comprise this dataset.

The link to access the dataset is:

<https://onedrive.live.com/?redeem=aHR0cHM6Ly8xZm1zL2YvYy85ZjZmNTQ4ZGFkMDc1MzQzL0VvYjVWZmRlZVZ3psTmdaZ0k2YTk5eWdNQIBINERfYThVTFV4QnN3Y2RFZi1ta3c%5FZT1qQ2RlZzU&id=9F6F548DAD075343%21s8e49cdbca87a493cb0134ac61f60ffd6&cid=9F6F548DAD075343&sb=name&sd=1>

Coastal Flood – Cyclones

This directory contains files related to hotel risk for the coastal flooding hazard (cyclones), including results disaggregated by canton, province, MIDEPLAN regional division, and Tourism Planning Units (UPT), as well as aggregated results at the national level.

File	Format
Hoteles_Canton_InundaCostera_Ciclones_CR-SIRGAS	.shp
Hoteles_Canton_InundaCostera_Ciclones_WGS84	.shp
Hoteles_InundaCostera_Ciclones_CR-SIRGAS	.shp
Hoteles_InundaCostera_Ciclones_WGS84	.shp
Hoteles_Provincia_InundaCostera_Ciclones_CR-SIRGAS	.shp
Hoteles_Provincia_InundaCostera_Ciclones_WGS84	.shp
Hoteles_REG_MIDEPLAN_InundaCostera_Ciclones_CR-SIRGAS	.shp
Hoteles_REG_MIDEPLAN_InundaCostera_Ciclones_WGS84	.shp
Hoteles_UPT_InundaCostera_Ciclones_CR-SIRGAS	.shp
Hoteles_UPT_InundaCostera_Ciclones_WGS84	.shp

The *.shp files used in this project are available in vector format and require a Geographic Information System (GIS) for visualization.

Coastal Flood – Tsunami

This directory contains files related to hotel risk for the coastal flooding hazard (tsunami), including results disaggregated by canton, province, MIDEPLAN regional division, and Tourism Planning Units (UPT), as well as aggregated results at the national level.

File	Format
Hoteles_Canton_InundaCostera_tsunami_CR-SIRGAS	.shp
Hoteles_Canton_InundaCostera_tsunami_WGS84	.shp
Hoteles_InundaCostera_tsunami_CR-SIRGAS	.shp
Hoteles_InundaCostera_tsunami_WGS84	.shp

Hoteles_Provincia_InundaCostera_tsunami_CR-SIRGAS	.shp
Hoteles_Provincia_InundaCostera_tsunami_WGS84	.shp
Hoteles_REG_MIDEPLAN_InundaCostera_tsunami_CR-SIRGAS	.shp
Hoteles_REG_MIDEPLAN_InundaCostera_tsunami_WGS84	.shp
Hoteles_UPT_InundaCostera_tsunami_CR-SIRGAS	.shp
Hoteles_UPT_InundaCostera_tsunami_WGS84	.shp

Fluvial Flood

This directory contains files related to hotel risk for the fluvial flooding hazard, including results disaggregated by canton, province, MIDEPLAN regional division, and Tourism Planning Units (UPT), as well as aggregated results at the national level.

File	Format
Hoteles_Canton_inunda_fluvial_CR-SIRGAS	.shp
Hoteles_Canton_inunda_fluvial_WGS84	.shp
Hoteles_inunda_fluvial_CR-SIRGAS	.shp
Hoteles_inunda_fluvial_WGS84	.shp
Hoteles_Provincia_inunda_fluvial_CR-SIRGAS	.shp
Hoteles_Provincia_inunda_fluvial_WGS84	.shp
Hoteles_REG_MIDEPLAN_inunda_fluvial_CR-SIRGAS	.shp
Hoteles_REG_MIDEPLAN_inunda_fluvial_WGS84	.shp
Hoteles_UPT_inunda_fluvial_CR-SIRGAS	.shp
Hoteles_UPT_inunda_fluvial_WGS84	.shp

Pluvial Flood

This directory contains files related to hotel risk for the pluvial flooding hazard, including results disaggregated by canton, province, MIDEPLAN regional division, and Tourism Planning Units (UPT), as well as aggregated results at the national level.

File	Format
Hoteles_Canton_inunda_pluvial_CR-SIRGAS	.shp
Hoteles_Canton_inunda_pluvial_WGS84	.shp
Hoteles_inunda_pluvial_CR-SIRGAS	.shp
Hoteles_inunda_pluvial_WGS84	.shp
Hoteles_Provincia_inunda_pluvial_CR-SIRGAS	.shp
Hoteles_Provincia_inunda_pluvial_WGS84	.shp
Hoteles_REG_MIDEPLAN_inunda_pluvial_CR-SIRGAS	.shp
Hoteles_REG_MIDEPLAN_inunda_pluvial_WGS84	.shp
Hoteles_UPT_inunda_pluvial_CR-SIRGAS	.shp
Hoteles_UPT_inunda_pluvial_WGS84	.shp

Earthquake

This directory contains files related to hotel risk for the earthquake hazard, including results disaggregated by canton, province, MIDEPLAN regional division, and Tourism Planning Units (UPT), as well as aggregated results at the national level.

File	Format
Hoteles_Canton_sismo_CR-SIRGAS	.shp
Hoteles_Canton_sismo_WGS84	.shp
Hoteles_sismo_CR-SIRGAS	.shp
Hoteles_sismo_WGS84	.shp
Hoteles_Provincia_sismo_CR-SIRGAS	.shp
Hoteles_Provincia_sismo_WGS84	.shp
Hoteles_REG_MIDEPLAN_sismo_CR-SIRGAS	.shp
Hoteles_REG_MIDEPLAN_sismo_WGS84	.shp
Hoteles_UPT_sismo_CR-SIRGAS	.shp
Hoteles_UPT_sismo_WGS84	.shp

RDLS Metadata

This directory contains the metadata following the Risk Data Library Standard, providing structured information to describe, organize, and ensure the consistency of the datasets used in the project.

File	Format
Loss_Tourism	.json

The *.json file may contain information related to hazard, exposure, vulnerability, or loss, depending on the type of data being represented within the project.