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Quantifying Future Flood Risk in Sri Lanka: A Smart Data Approach for Insurance Pricing and Strategy

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Abstract

Sri Lanka is increasingly vulnerable to flooding due to climate change, unplanned urban expansion, and insufficient infrastructure resilience. Despite this, the current insurance regulatory framework under the Risk-Based Capital (RBC) regime does not explicitly incorporate a catastrophic (CAT) risk charge for natural disasters such as floods. This paper proposes a novel framework for quantifying future flood risk in Sri Lanka using a smart data approach that integrates hydraulic modeling (HEC-RAS), geographic information systems (GIS), and machine learning (ML). The framework enables the generation of flood hazard maps, estimation of event probabilities, and calculation of expected losses at property level. A simulation-based approach is then used to determine the capital required to cover extreme loss events, which can serve as the basis for a CAT risk charge. Although full implementation is pending, this paper presents an illustrative model using synthetic data to demonstrate the methodology and its potential implications. By embedding flood risk into pricing and strategic decisions, this approach aims to improve insurance sector resilience and inform regulatory advancement. The results highlight the feasibility and urgency of adopting data-driven tools to better manage climate-induced risks in Sri Lanka.

Keywords: Climate, Flood risk, Hazard modeling, Smart data.

Introduction

The challenge and why this matters for actuaries

Sri Lanka faces a growing threat from floods, driven by our unique monsoon patterns and intensified by climate change, along with rapid, often unplanned, urban growth. This leads to significant financial losses for properties and businesses. As actuaries, we recognize that our current insurance regulatory framework, particularly under the Risk-Based Capital (RBC) regime, does not explicitly require us to set aside specific capital for catastrophic natural disasters like floods. This means we're likely not fully accounting for the true risk in our pricing or our solvency management, leading to potential mispricing, inadequate capital buffers, and a large gap in protection for the market. This research aims to provide a robust framework to quantify flood risk, both for setting appropriate pricing and for determining the necessary capital charge for extreme, rare flood events.

Methodology

Data used

- **Location data (GIS):** This includes detailed digital maps of Sri Lanka (or selected river basin maps)

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showing ground elevation, slopes, rivers and drainage systems, how land is used (e.g., urban areas, forests, farmland), and the location of key infrastructure. This helps us visualize *where* floods could occur and *what* could be affected.

- **Climate data:** We collected historical rainfall records from various weather stations, including details on daily and even hourly rainfall. Crucially, we'll also use projections from climate scientists about *how rainfall patterns are expected to change in the future* – for instance, predicting more frequent or intense downpours due to climate change.
- **Insured property data:** This is our core business data. We'll need the exact geographic location of each insured property, its insured value, type of construction (e.g., concrete, brick), age, and number of floors. We'll also use our own historical flood claims data, including the date of loss and the actual payout amounts.

Development of the Risk Model

Mapping flood danger (hazard modeling)

- Using our location data and rainfall information, we'll employ specialized hydrological and hydraulic modeling software (specifically HEC-RAS). This software helps us simulate how water flows across the landscape and within river systems during various rainfall events.
- The output will be detailed flood hazard maps. These maps will show *where* flooding is expected to occur and *how deep* the water will be for different types of rain events (e.g., a common heavy rain event, or a very rare, extreme storm that might occur only once every 100 years). This also helps us estimate the probability of these events occurring.

Estimating property damage (vulnerability assessment)

- For each type of property (e.g., a residential house, a commercial building), we'll develop "depth-damage functions." These are rules that tell us, based on the expected flood depth at a property, what percentage of its value is likely to be damaged.
- By combining the flood hazard maps with our insured property data, we can then estimate the Gross Loss (total economic damage) and, after applying policy deductibles and limits, the Net Loss (what the insurance company would actually pay out) for each property for every possible flood scenario.

Calculating expected annual loss (EAL) for pricing

- We will use Machine Learning (ML) algorithms. We'll train these ML models using our historical property, rainfall, and claims data. The models will learn the complex relationships between these factors and past flood losses.
- The primary output of this ML model will be the Expected Annual Loss (EAL) for *each individual insured property*. The EAL represents the average claim cost we expect from floods for that property in a given year. This EAL is the fundamental basis for setting the pure flood risk premium.
- Crucially, to account for climate change, we will feed the ML models with future rainfall **projections** (e.g., predictions of more intense or frequent heavy rain events).

This allows the models to project how the EAL – and thus the underlying pure flood risk – is expected to increase for each property in future years.

Simulating extreme losses for catastrophe (cat) capital charge

- Beyond just the average annual loss (EAL), regulators (under the RBC regime) require capital to be held for very rare, but extremely severe, loss events. To determine this CAT capital charge, we will use a simulation-based approach.
- This involves running thousands of simulations of plausible future flood events across our entire

portfolio of insured properties. Each simulation will combine different rainfall scenarios, their probabilities, and the resulting property-level net losses.

- By analyzing the distribution of these aggregate losses across all simulations, we can statistically determine the capital required to cover extreme loss events (e.g., the 1-in-200 year loss, or the 99.5th percentile of losses). This calculated capital amount then forms the explicit basis for a CAT risk charge in the context of solvency requirements.

Conclusions

Strategic impact

The findings of this research will have significant implications for the Sri Lankan insurance industry and its regulators:

- It will provide the quantitative basis for introducing transparent, actuarially sound flood risk charges into pricing, directly linked to the calculated EAL.
- It will enable insurers to better manage their capital, ensuring sufficient reserves for extreme flood events as required by the RBC regime.
- The insights will support enhanced underwriting, allowing for more precise risk selection.
- By highlighting areas of increasing risk due to climate change, this framework will inform broader national strategies for disaster risk financing, urban planning, and climate change adaptation, ultimately aiming to build a more resilient Sri Lanka.