Technical Note: Parametric Crop Insurance Design for Indore Block

- **Product:** Soybean Excess Rainfall Cover (Harvest Season).
- **Risk Period:** October 1st – October 31st
- **According to:** ERA5-Land Historical Weather Data (2005-2024).

1. Executive Summary

This report presents the design and actuarial calibration of a parametric insurance product among Soybean farmers in the Indore Block. Through the product, there is protection against the excess rainfall that falls during the harvesting season. Based on 20 years of past weather records, we have created an index-based cover that uses a calibration model that pays when the cumulative rainfall during the month of October becomes more than critical levels. This model costs 5% premiums (₹2,500) with a high catastrophe cover for the year.

2. Data & Methodology

- **Geographical Scope:** Indore Block.
- **Weather Data:** ERA5-Land Gridded Dataset (0.1° x 0.1° resolution).
- **Risk Index Construction:** To minimize spatial variance, we aggregated daily rainfall across all grid points within the block geometry to create a representative "Block Average Daily Rainfall." Such daily averages were further added up to form a Cumulative Monthly Rainfall Index of each year (2005-2024).

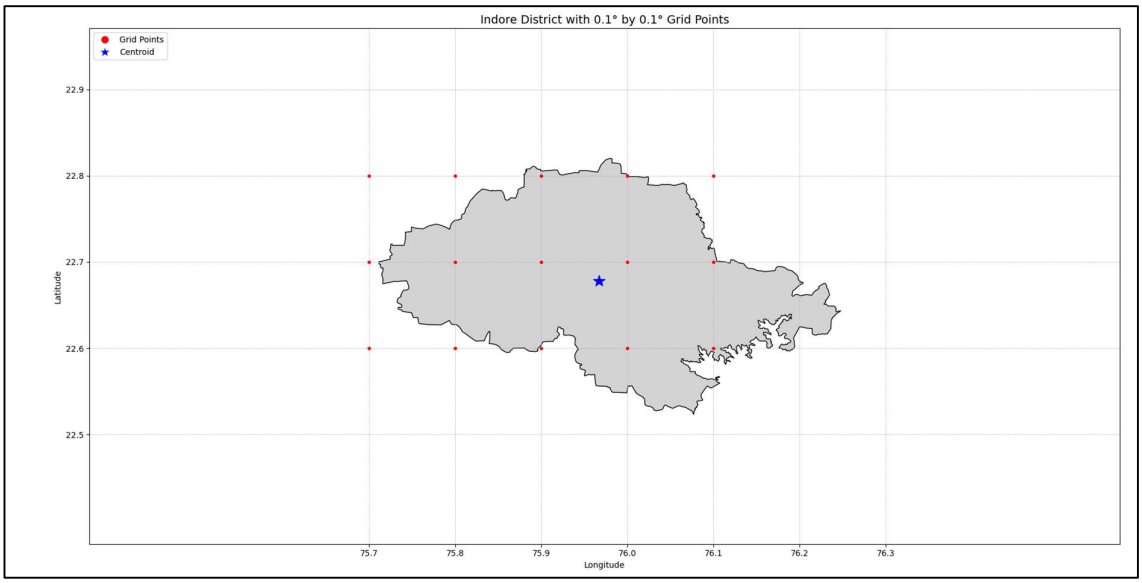

Figure 1: Indore Block Geometry showing grid points used for rainfall aggregation.

3. Risk Profile & Threshold Logic

We used the 20-year history to analyze the risk profile in the region, and as shown in Figure 2, it is Bimodal.

- **Normal Phase (70% probability):** Rainfall was hardly sufficient (< 30mm) in 13 out of 20 years, and it did not constitute any significant danger to the harvest. Evaluation of the past 20 years of the average total Rainfall in October shows that it is approximately 31.9 mm. This is our reference point for normal weather.
- **Catastrophe Phase (30% growth):** Within the last 7 years, the growth of rainfall was very sharp and exceeded 60mm (i.e., 2009, 2013, 2019, 2021, 2022, 2024) with one exception of 2016. These spikes are associated with the spoilage of the harvest. Analyzing the aggregated data (Figure 2), we can obviously observe clear "Catastrophe Years" in which the rainfall had significant deviation from the mean:
- **2013:** ~62.5 mm (High)
- **2019:** ~84.7 mm (Extreme)
- **2024:** ~73.8 mm (High)

Trigger Decision: These spikes define our payout structure. The average policy won't cut it. We need a setup that pays in extreme years-over +60 mm, while ignoring small anomalies, such as 2012 or 2020, to keep premiums affordable. This is what we call the 5% Rule. We've set 60mm as the entry trigger. This sits at the safe-year maximum and disaster-year minimum, reducing false positives and preserving the premium budget for true losses.

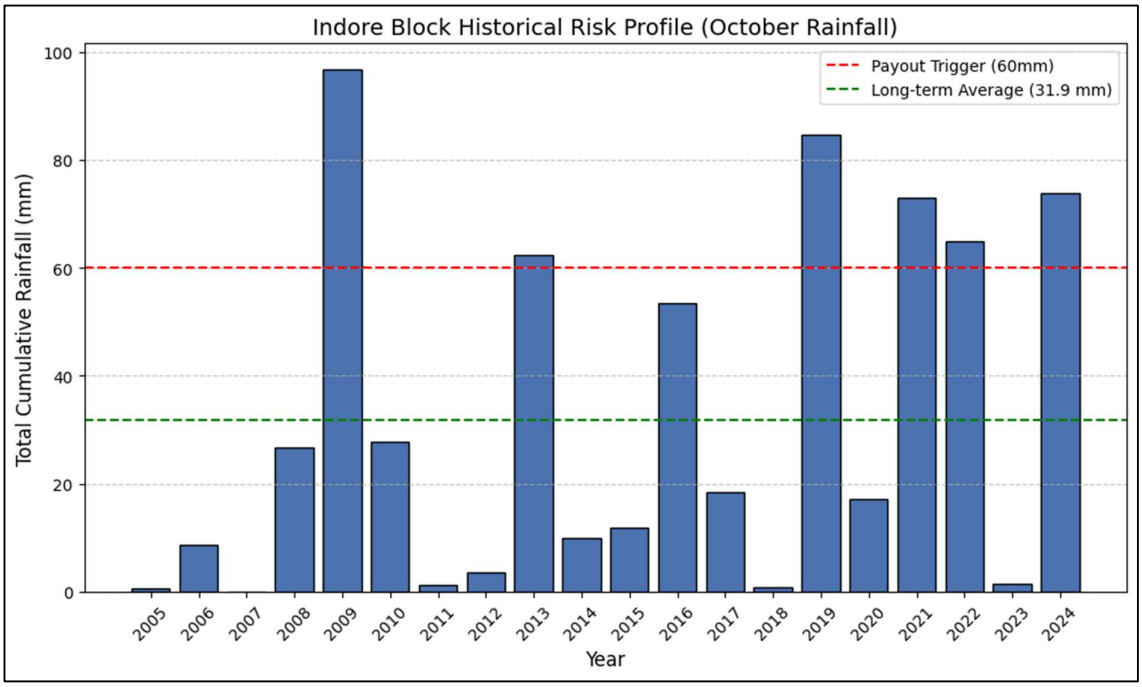

Figure 2: Distribution of past Rainfall. The line in red marks the 60mm trigger threshold.

4. Payout Design & Calibration

As a measure to match compensation and the extent of crop damage, we constructed a 3-Slab Step Function payout structure.

- **Sum Insured (SI):** ₹50,000 per acre.
- **Target Premium:** ₹2,500 per acre (5% of SI).

Risk Level	Rainfall Threshold	Payout Amount (₹)	Logic
Normal	0 – 60 mm	₹ 0	Crop is safe.
Moderate	> 60 mm	₹ 5,000	Quality loss due to moisture.
Severe	> 70 mm	₹ 8,000	Significant pod damage.
Catastrophic	> 80 mm	₹ 12,000	Widespread rot / total loss.

Calibration Result: Using the "Burning Cost" method, we back-tested this structure over the last 20 years. To meet the pricing constraint, the catastrophic slab was calibrated from an initial ₹12,500 down to ₹12,000.

- **Target Average Payout:** ₹2,500
- **Modeled Average Payout:** ₹2,500
- **Status: Perfectly Calibrated.**

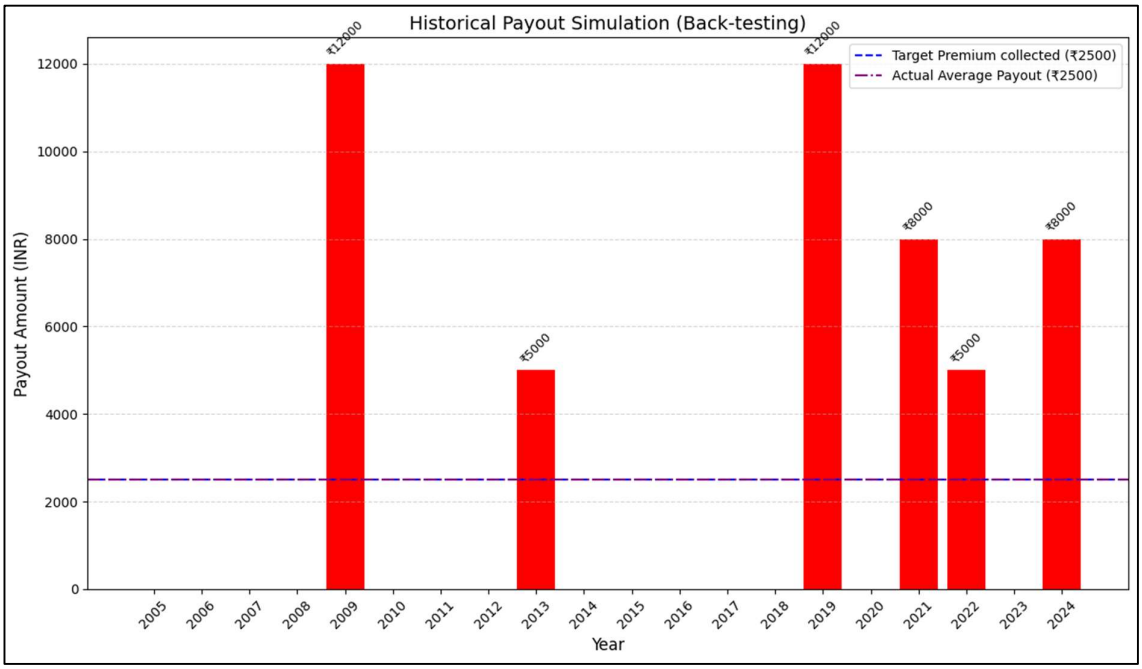

Figure 3: Simulated Payouts (2005-2024). The years in which farmers would have been awarded claims are represented by red bars.

5. Advanced Actuarial Validation (Model Robustness)

To test the empirical pricing model, we completed two higher-order statistical tests:

A. Stochastic Distribution Analysis (Fat Tail Detection). To compare the theoretical and actual risk, a Gamma Distribution (Shape=0.58, Scale=41.50) was fit to the historical data.

- **Results:** The theoretical Gamma model indicated that the probability of a loss (Rain > 60mm) was only 10.9% which was much lower than the historical probability of 30.0%.
- **Conclusion:** This difference shows that Indore's rainfall is fat-tailed, meaning that extremes are more common than standard statistics predict. Those bolsters use the Empirical Burning Cost method, since a normal parametric curve would have underpriced the risk and thereby jeopardized the insurer.

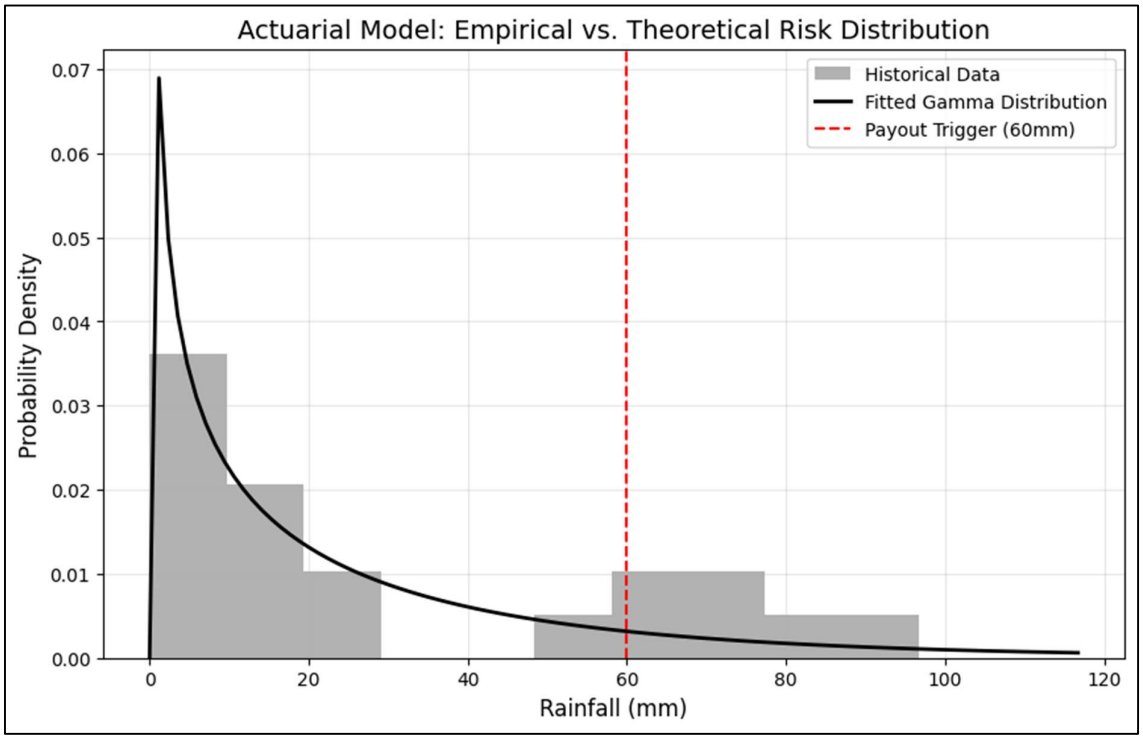

Figure 4: Empirical vs. Theoretical Probability Density.

B. Climate Sensitivity Stress Test. We stress-tested the product under a Climate Change Scenario, where there was a 10 percent change in the intensity of rainfall in all years.

- **Results:** Under this scenario, the pure risk premium rises from ₹2,500 to ₹3,050, a 22.0% increase.
- **Conclusion:** The non-linear leverage of this payout structure is that a 10 percent weather change will lead to a 22 percent increase in costs. We suggest the insurer develop a buffer of 15-20% of future premiums of Climate Loading or check triggers after every 2 years.

6. Basis Risk & Limitations

The primary limitation is Spatial Basis Risk. The product uses satellite data averaged over the entire Indore block.

- **Type 1 Error (False Negative):** A specific farmer might experience a localized cloudburst flooding their field, but the block-average rainfall remains below 60mm. They suffer a loss but receive no payout.
- **Measurement Discrepancy:** ERA5 is a reanalysis dataset and may differ from physical rain gauges on the ground, potentially leading to disputes.

7. Suggestion for Improvement

If available, incorporating Satellite Soil Moisture Data, such as NASA SMAP, would greatly enhance the product. High rainfall does not always induce rot if the soil drains rapidly. A trigger based on "Saturation Duration" (soil moisture >90% for 3 consecutive days) is a better biological proxy for fungal growth and crop spoilage than rainfall volume alone.

8. Farmer Communication

Indore Soybean Cover: Protect your hard work this harvest! If the total October rainfall in the Indore block crosses 60mm, you get paid automatically. No forms, no farm visits.

- Rain > 60mm: Pay ₹5,000
- Rain > 70mm: Pay ₹8,000
- Rain > 80mm: Pay ₹12,000. Money is sent directly to your bank account.