Insurance for Soybean Crop in Indore

Introduction:

The soybean was introduced into India in the 1970s to diversify agricultural production and strengthen food security measures. Over the years, it became paramount in Madhya Pradesh; Indore district became an excellent example of successful soybean cultivation.

Soybean is a kharif crop and is usually cultivated from June to early November. Its production has been on the rise in Indore and Madhya Pradesh as farmers are increasingly adopting modern farming practices such as fertilizers, pesticides, and genetically modified seeds as an aid in maximizing yield and pest management.

Soybean crop mainly undergoes three developmental stages: vegetative growth stage (June-August), flowering stage (August-September), and reproductive/podding stage (October-November). In the vegetative growth stage, soil moisture depletion should not range below 15-50%, while in flowering and reproductive stages, maintaining soil moisture at 30-50% is advisable.[1]

The dominant soil type in the district is black cotton soil, known for moisture retention and fertility, particularly favourable for soybean cultivation. Rainy climatic conditions assist in providing nearly sufficient water for plant growth predominantly due to monsoon rains. Black cotton soil has a volumetric moisture content at field capacity of around 30-45%. If we take the midpoint of 40%, moisture depletion during the vegetative growth stage should not exceed 50%, and therefore at least 20% moisture must be retained. During flowering and reproductive stages, moisture depletion should be lower; otherwise, greater moisture depletion may result in a huge reduction in yield. In these two stages, at least 28% moisture should remain in soil.[2]

Although farmers have adopted new technologies and practices to boost crop yields, they remain heavily dependent on weather conditions, with the monsoon continuing to play a crucial role in overall production. Given the unpredictability of the climate and the increasing demand for soybeans in India, there is significant potential for insurance products to help mitigate the risks posed by climate variability.

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[1] Food & Agriculture Organisation of UN : https://www.fao.org/land-water/databases-and-software/crop-information/soybean/en/#:~:text=Water%20requirements%20(ETm)%20for%20maximum,and%20at%20harvest%200.4%2D0.5

[2] IRAJ: https://www.iraj.in/journal/journal_file/journal_pdf/13-582-15681869344-8.pdf

Perils to be Covered:

Soybean requires moderate rainfall during its growing stage and dry weather during maturation. The crop is highly sensitive to both rainfall variability (deficit or excess) and temperature extremes, such as high temperatures during germination or flowering. The key perils that significantly affect soybean yield are excess rainfall, deficit rainfall, and high-temperature stress.

- Excess Rainfall: Causes waterlogging, particularly during the vegetative growth stages. Heavy rains leading to waterlogged conditions, especially from June to August, can damage the crop, hampering both growth and flowering, and ultimately reducing yield.
- Deficit Rainfall: Affects the flowering and reproductive stages most severely. Below-normal rainfall during the critical sowing and vegetative stages (June–July) can result in poor crop establishment and reduced yields.
- Temperature Stress: High temperatures during the flowering stage (August–September) can lead to significant yield losses. Extreme heat during this period can hinder pollination and pod formation, impacting overall crop productivity.[3]

These climatic risks highlight the need for effective weather monitoring and management strategies to optimize soybean yields.

Trigger Mechanism:

I have introduced triggers to identify whether the above risk events have occurred.

Excess Rainfall:

The trigger mechanism for excess rainfall is as follows:

If the cumulative monthly rainfall for the June–November period exceeds 10% of the long-period average (LPA) for those months. The LPA calculation is adjusted to determine the threshold value for June–November.

We use a 3-day moving average for rainfall to detect rainfall above 64.5 mm for two consecutive days, as soybean can tolerate two days of excessive rainfall. According to the IMD, rainfall above 64.5 mm is considered heavy. Since we are using a 3-day moving average, we set the threshold at 58 mm. If the 3-day average exceeds 58 mm, it is likely that rainfall for at least two days has surpassed 64.5 mm. This method helps avoid skewing results by a single dry day, as consecutive days of heavy rain cause more stress to the soybean crop.

To ensure the impact is significant, we introduce another checkpoint using the moving average soil water level. If the soil water level exceeds 50% in general or 47% specifically for August, it indicates a potential flooding situation, which would significantly affect crop yield.

[3] Food & Agriculture Organisation of UN : https://www.fao.org/land-water/databases-and-software/crop-information/soybean/en/#:~:text=Water%20requirements%20(ETm)%20for%20maximum,and%20at%20harvest%200.4%2D0.5

Deficit Rainfall:

The trigger mechanism for deficit rainfall is as follows:

The trigger mechanism for deficit rainfall is as follows:

- If the cumulative monthly rainfall for the June–November period is 10% less than its long-period average (LPA). According to the Indian Meteorological Department (IMD), rainfall is considered deficit if the cumulative annual rainfall is 20% less than the LPA. However, for the June–September period, a 10% deficit from the LPA is used. The LPA is calculated based on cumulative rainfall for each month from 1980 to 2023.
- Next, we check if the monthly average maximum temperature exceeds 35°C, as soybean yield is significantly affected by temperatures above this threshold. The ideal temperature range for soybean is between 20°C and 30°C, and beyond 35°C, the crop may not survive the season.
- Finally, we assess whether the moving average of the soil water level is less than 20% for the months of June–September, and less than 30% for October–November.

Temperature Stress:

The trigger mechanism for high-temperature stress is as follows:

- If the maximum monthly temperature exceeds 33°C, it could be dangerous for soybean yield. This specific threshold is chosen because soybean yield is significantly affected when temperatures exceed 35°C, leading to increased soil water depletion. A monthly average above 33°C suggests a high likelihood of multiple days with temperatures above 35°C.
- A 10-day moving average is used to monitor maximum temperatures greater than 35°C.
- Lastly, we check if the soil water level is below 20% for June–September and below 30% for October–November.

This is how I use these triggers to monitor extreme climatic events and their impact on soybean yield.

Modelling and Pricing Approach:

Risk Assessment:

For each climatic risk, we will evaluate the loss frequencies and loss severity. This means that for the past 12 years, we will analyse how often each risk occurred and calculate the average yield loss.

	DateTime	Excess_Rainfall	Deficit_Rainfall	Extream_Heat	Yield (Tonne/Hectare)
0	2011	0	0	9	1.16
1	2012	0	0	0	1.45
2	2013	1	0	0	1.01
3	2014	0	0	6	1.06
4	2015	0	29	24	0.76
5	2016	0	0	0	1.59
6	2017	0	0	7	0.91
7	2018	0	0	13	1.49
8	2019	1	0	0	1.50
9	2020	3	0	0	1.26
10	2021	0	0	0	1.02
11	2022	0	0	0	1.24

Using the data from the past 12 years as shown earlier, we can calculate the loss frequency and loss severity as follows:

Definitions:

Loss Frequency (for a peril): The number of years in which at least one trigger for the risk was breached.

Average Yield: The average of the top four maximum yields over the 12 years.

Loss Severity (for a peril): (Weighted average yield loss) × (Average Yield) × (Soybean MSP).

Expected Loss per Hectare: Loss Frequency × Loss Severity.

Calculation:

Loss Frequencies: Freq_1 (for Risk 1) = 0.25, Freq_2 (for Risk 2) = 0.083 &Freq_3 (for Risk 3) = 0.416

Baseline Yield (Threshold Yield): 1.59 tons per hectare

Yield Losses: Yield Loss 1 = 0.16, Yield Loss 2 = 0.27 & Yield Loss 3 = 0.23

Loss Severities: Loss Severity 1 = ₹12,265.75, Loss Severity 2 = ₹20,000.56 & Loss Severity 3 = ₹17,100.23

Expected Loss per Hectare: Expected Loss 1 = ₹3,066.43, Expected Loss 2 = ₹1,666.71 & Expected Loss 3 = ₹7,125.09

Expected Total Loss: ₹11,858.25 per hectare

Premium Calculation:

The premium is calculated as the expected total loss plus the loading factor. The loading factor includes reinsurance costs, profit margin, and contingency margin, which generally range from 15% to 25%. Assuming a 15% loading factor, the premium would be:

Premium Calculation:
Premium = ₹11,858.25 + (15% of ₹11,858.25)
Premium = ₹11,858.25 + ₹1,778.74
Premium = ₹13,637 per hectare

This amounts to 18.86% of the total expected yield value. This is the premium for full coverage of the crop.

Payout Structure:

Coverage Levels for Different Payout Schemes: Farmers can choose different coverage levels depending on their preferences:

- 60% Coverage: Payout begins when losses exceed 40% of the expected yield, with a premium of ₹8,706.60.
- 80% Coverage: Payout begins when losses exceed 20% of the expected yield, with a premium of ₹11,608.80.
- 100% Coverage: Full coverage with payouts for any loss in yield.

Payout Structure for Different Perils:

1. **Excess Rainfall:**
   To calculate the average yield loss if the excess rainfall trigger is breached one time, we use the formula:
   - Average Yield Loss = (Yield Loss 1 / Total Number of Breaches) = 9.98%.

   Payouts for Excess Rainfall:
   - 60% Coverage:
     - No payout occurs if the number of breaches is less than 5.
     - Payout = ₹73,350 × ((n × 0.0998) – 0.4), where n is the number of excess rainfall breaches, and n ≥ 5.
   - 80% Coverage:
     - No payout occurs if the number of breaches is less than 3.
     - Payout = ₹73,350 × ((n × 0.0998) – 0.2), where n ≥ 3.
   - 100% Coverage:
     - Payout = ₹73,350 × (n × 0.0998), where n is the number of excess rainfall breaches.

2. **Deficit Rainfall:**
   To calculate the average yield loss if the deficit rainfall trigger is breached one time, we use the formula:

   - Average Yield Loss = (Yield Loss 2 / Total Number of Breaches) = 0.93%.

   Payouts for Deficit Rainfall:

   - 60% Coverage:
     - Payout = ₹73,350 × ((n × 0.0093) – 0.4), where **n** is the number of deficit rainfall breaches.
   - 80% Coverage:
     - Payout = ₹73,350 × ((n × 0.0093) – 0.2), where **n** is the number of deficit rainfall breaches.
   - 100% Coverage:
     - Payout = ₹73,350 × (n × 0.0093), where **n** is the number of deficit rainfall breaches.

3. **Temperature Stress (Extreme Heat):**
   To calculate the average yield loss if temperature stress (extreme heat) occurs, use the formula:

   - Average Yield Loss = (Yield Loss 3 / Total Number of Breaches) = 1.96%.

   Payouts for Temperature Stress (Extreme Heat):

   - **60% Coverage:**
     - Payout = ₹73,350 × ((n × 0.0196) – 0.4), where **n** is the number of temperature stress breaches.
   - **80% Coverage:**
     - Payout = ₹73,350 × ((n × 0.0196) – 0.2), where **n** is the number of temperature stress breaches.
   - **100% Coverage:**
     - Payout = ₹73,350 × (n × 0.0196), where **n** is the number of temperature stress breaches.