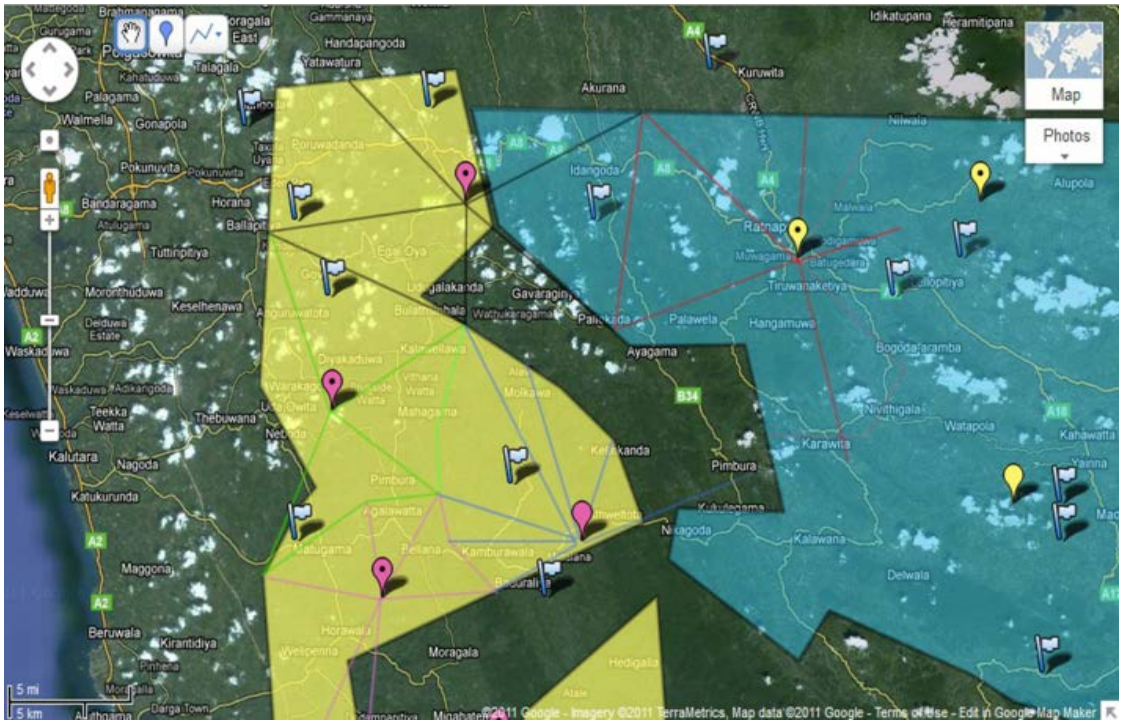
Weather Index Insurance

A Technical Perspective

The Concept

- What is Weather Index Insurance?
  - Based on an index specific for each crop. Eg: rainfall is the weather variable for rice
  - All farmers located within a specific radius of the weather station can be covered
  - Payout is made to the farmer based on the recorded weather value specific to the time period
  - No field visits : reduces survey and administrative costs

The Concept



A major concept in Weather index Insurance is Basis Risk. Figures highlighted under color are the tea growing areas in Sri Lanka. The Colored Markers are the weather stations under consideration and the lines depict the area they would cover. A radius of approximately 12 to 15 km suffices in managing basis risk to a considerable extent. The flags are the stations not considered.

Some Terms

- Basis Risk: The risk that the weather experienced is different then that recorded at the weather station.
- Trigger: The value of the weather variable at which the payout commences
- Stop Loss: The Value of the weather variable where the Payout reaches its maximum value. Beyond the Stop loss only the Maximum value is paid out.

The Concept

- Example of a Weather Index: For a risk period starting from the 1st to 30th of a month the cumulative rainfall recorded during the month.
- The indemnity is paid according to the equation:

Let x = cumulative rainfall
y = Minimum Pay-out
z = Pay-out per mm
a = Trigger
b = Stop loss

Payout = 0	if x > a
Payout = y + (a-x)*z	if b < x <= a
Payout = y + (a – b)* z	if x <= b

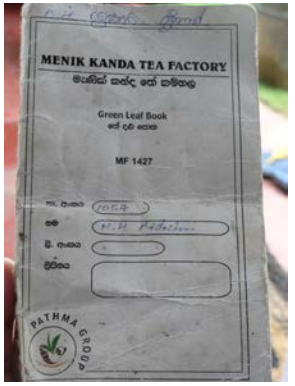
The Concept

- Example of the Payout Structure:
  - Weather Variable: Cumulative Rainfall p.m
  - Trigger : 100mm
  - Stop Loss: 20mm
  - Minimum Payout: Rs 300
  - Maximum Payout: Rs 3000
  - Payout Per mm: Rs 33.75
  - If rainfall recorded is 67 mm then payout to the farmer will be: 300 + (100 – 67)*33.75 = Rs 1413.75

The Concept

- How do we create the Index?
- How is the crop yield loss related to the index?
- How do we connect the yield to the loss to the weather variables so that:
  - We minimize basis risk
  - Maximize weather and crop loss correlation
- How do we calculate the Risk Premium?

Data Requirement



- What data is required?
  - Weather Data for at least the past thirty years. Why 30? – World Meteorological Organization
  - Yield Data: Depending upon the crop the monthly or seasonal yield per area (defined accordingly) for at least the past “few” years
  - Additional Data: Number of farmers in the area.

Sources of Data

- Weather Data: Meteorological Department
- Yield Data: Local Agricultural Body, Farmers, Market Authorities etc.
- Other Data: In our case we obtained the total numbers of farmers and the amount of tea leaves they were supplying for the past 120 months from a Tea Factory based in Ratnapura, Sri Lanka. The number of farmers amounted to more than 3000 per month.

Other Sources of Information

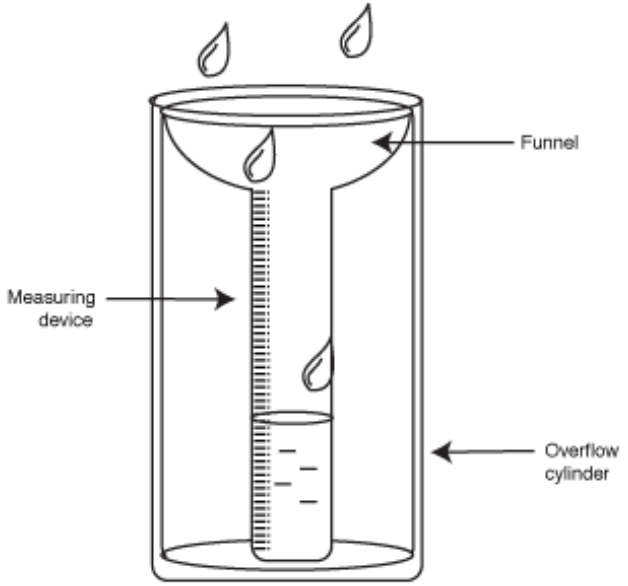
- Meetings with agronomists gave us a good idea regarding the crop cycle and weather requirements.
- Meetings with farmers enabled us to understand first hand the problems faced by them.
- We also conducted a survey of over 1000 farmers located throughout the island to understand the costs faced by them.
- A report was also commissioned from a reputed Sri Lankan Agricultural university for the crops under consideration. The report included all the information regarding the crops.

Reliability of the Data

- The more data you have the better but:
  - Garbage in – Garbage out
  - Which data is the correct representation of actual yields and how to identify it?
  - A lot of the weather data is missing.
  - Also, is the weather data accurate?
  - Agronomists intuition and judgment plays a crucial role in understanding the crop water requirements

Weather Measurement

- Which weather variables affect crops? – Rainfall, Temperature etc.
- What instruments do we use? – Rain gauge etc



Weather Station Feasibility

- To check the proper functioning of each station we visited all the stations considered for the project.
- The following points were considered for each weather station before deciding to use it for the project:
  - Automated/ manual
  - Security
  - Quality
  - Availability of a Backup

KALUTARA:

1. HALWATURA
2. GEEKIYANAKANDA
3. USK VALLEY ESTATE
4. SIRIKANDURA
5. PELAWATTA

GALLE:

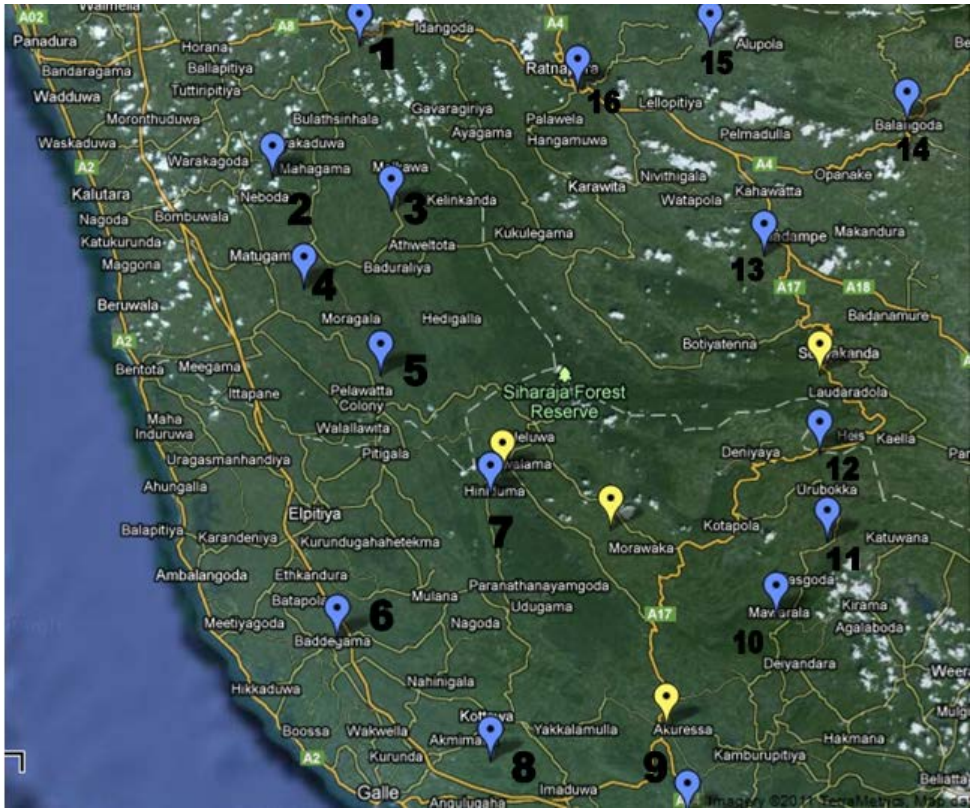
6. BADDEGAMA ESTATE
7. HINIDUMA
8. HIYARE

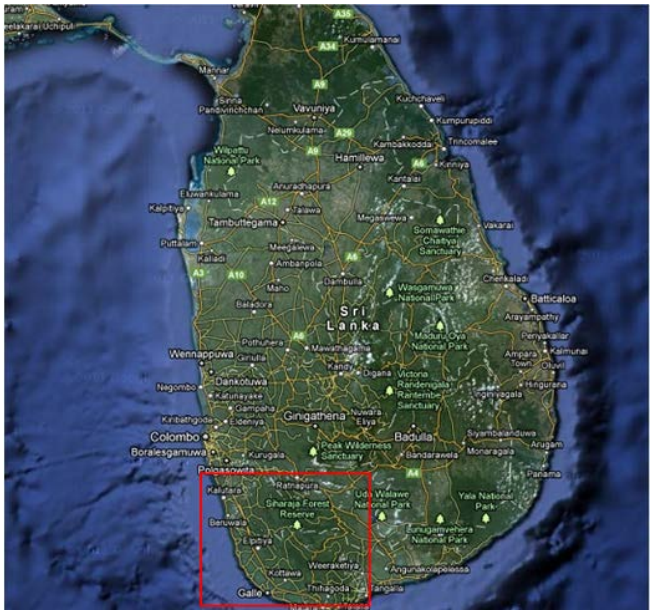
MATARA

9. TELIJAWILLA
10. MAWARELLA ESTATE
11. DAMPAHALA TEA FACTORY
12. ANNINGKANDA

RATNAPURA

13. WELLANDURA ESTATE
14. BALANGODA
15. HAPUGASTENA
16. RATNAPURA

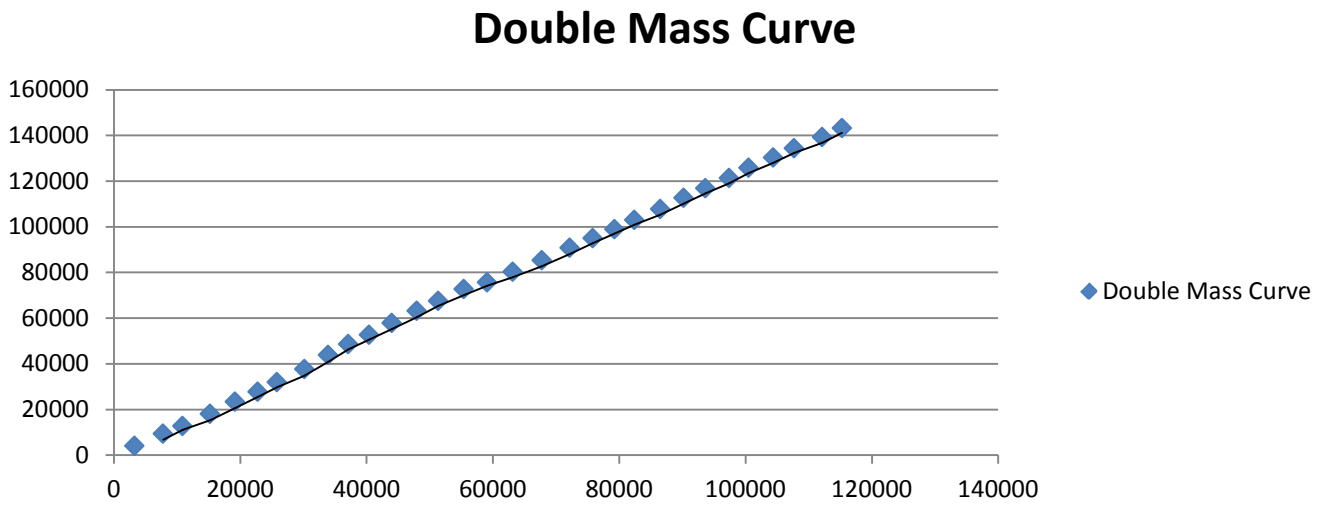




Data Analysis – Weather Data

- After receiving rainfall data we proceed with its validation and analysis.
- Data Analysis:
  - Filling Missing Data: Using Spatial Interpolation. Inverse Power Method.
  - Trend Analysis : Graphs of the rainfall were plotted against time and no trends were detected. Mann Kendall Trend test was used.
  - Check for Faulty Data: Plotting the double mass curve.

Double Mass Analysis



Identify a weather station which is Reliable and has the required number of years data which will serve as a base Station. We compare the other stations to this Base Station to identify if the other stations can be considered reliable. The double mass curve above is created by taking the running totals of each station and plotting them with base station values on the x-axis and the other station on the y-axis. If the other station shows signs of inconsistency in data recorded, it is visible as a break or a curve in the straight line. This is a necessary step in identifying unreliable stations.

Weather of Sri Lanka

- Sri Lanka has 56 climatic zones – Highest for any country.
- Although the weather stations exhibit significant correlation, the weather patterns experienced at a certain time are highly contrasting.
- Farmers are aware of this difference.

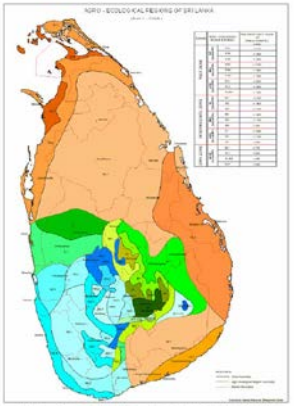
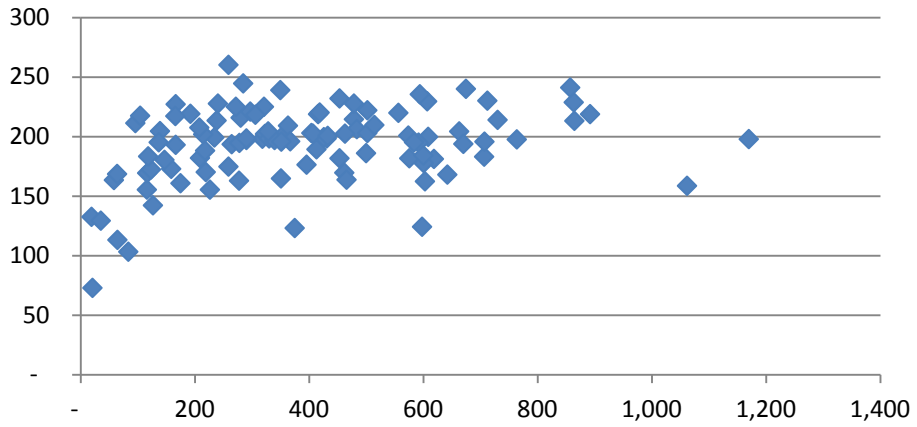


Fig 1. Agro climatic map of Sri Lanka (1979)

Obtaining a Relationship between Weather and Yield

- The Yield – Rainfall Curve
- Basic Goal is to obtain a relationship between the yield and the Weather Variable.

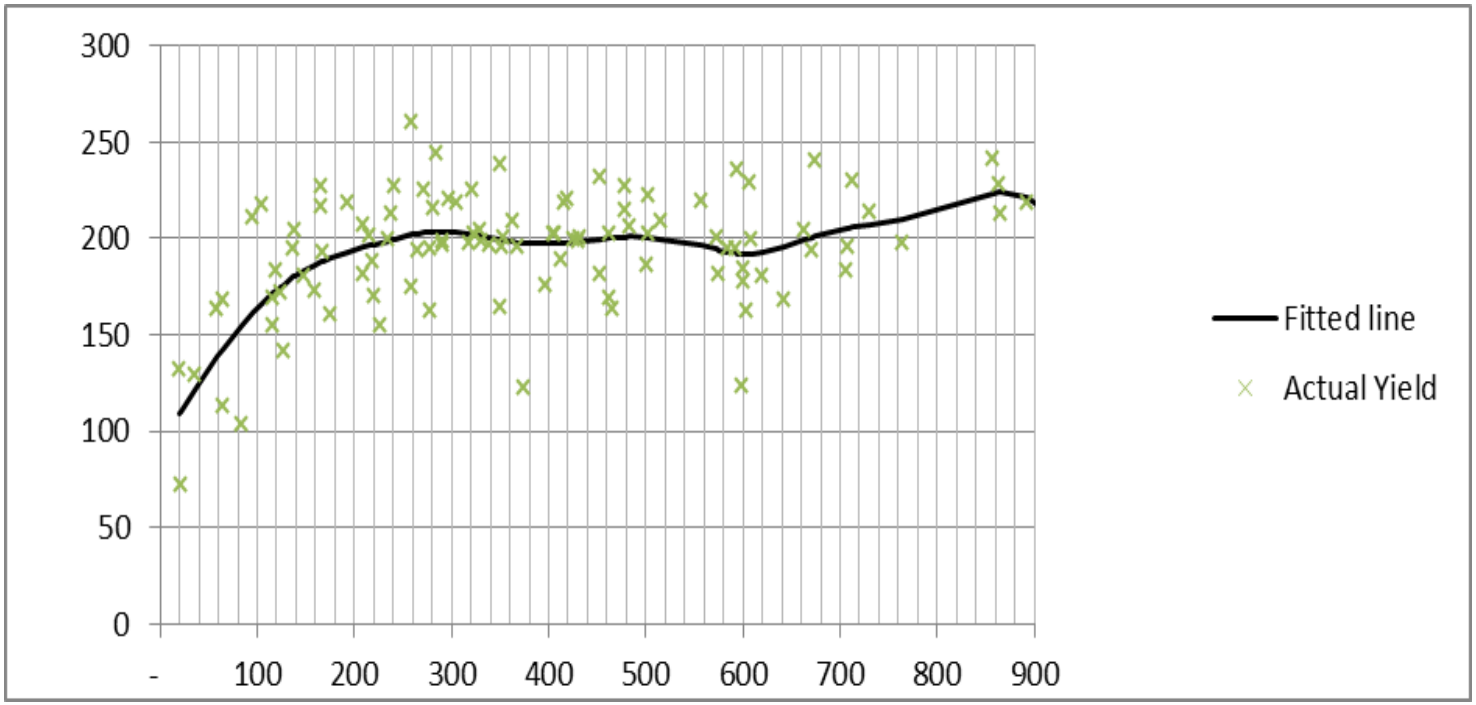


X- Axis : Cumulative Rainfall Per Month
Y-Axis: Average Yield Per Acre

Obtaining a Relationship between Weather and Yield

- Obtained using Parametric, or Non-Parametric Regression Techniques.
- Parametric Regression involves fitting an equation such that R-squared is maximized.
- R- Squared, the coefficient of determination, indicates how well data points fit a line or a curve.
- The more the data points, easier to validate the fit.
- Non-Parametric Regression technique does not involve fitting an equation. The Predictor variable is obtained from the data points themselves.
- Example : Kernel Regression

Curve Fitting

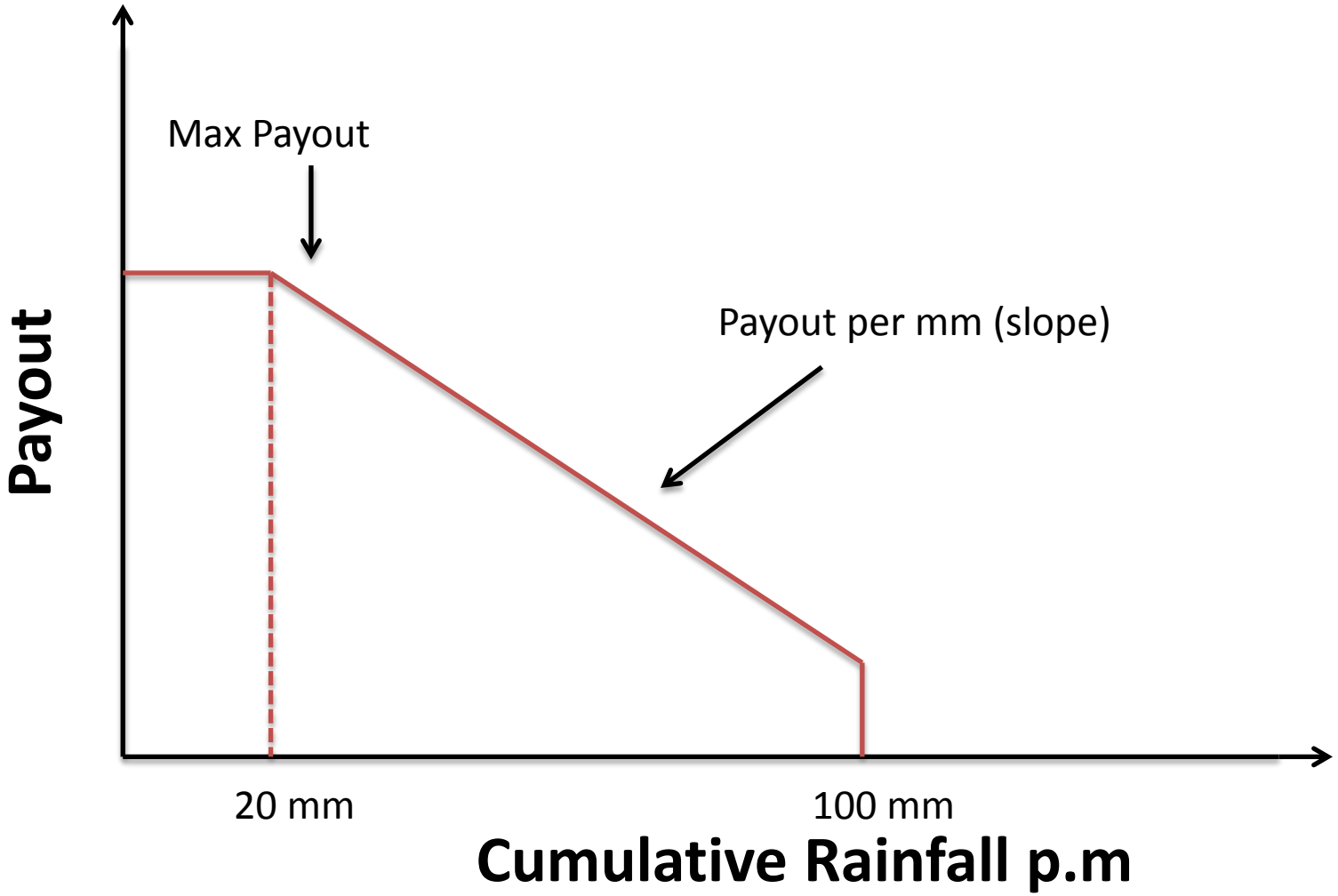


Refer Excel Sheet - Regression

The Relationship between Rainfall and Yield

- Agronomists intuition along with the regression line fit between weather and yield helps us understand how the crop will react to the weather variable.
- Using the results from the survey and other information gathered regarding the cost of cultivation, we then relate the yield to the Profit or loss experienced by the farmer to obtain the Payout Structure for each value of the weather variable

The Graphical demonstration of the Payout is as follows:



Setting up the Policy Structure

Hypothetical Policy Structure. Total Number of Days: 150 Days					
	Drought Side				
	No of days to Consider	Trigger	Stop Loss	Min Pay-out	Sum Insured
Vegetative	All 30 Days	45	15	1000	10000
Reproductive	All 30 Days	60	20	2000	20000
Ripening	30	NO PAYOUT	NO PAYOUT	NO PAYOUT	NO PAYOUT

Based on:

- Farmer's Survey and meetings
- Meetings with agronomists
- Technical Reports
- Simple and Easy to understand
- Policy Based on the target customer

Pricing Methods

- Now that we have the Payout/Policy Structure and all the Weather Data how do we calculate the Premium?
- Methods considered:
  - Burn Analysis
  - Numerical Integration

Burn Analysis

- This is the first method used to calculate the Risk Premium for the contingent claim
- A simple and a highly effective method, it gives us a good approximation of what the actual pure premium for each weather station would be.
- Based on past weather data, it assumes weather conditions in the future will be reminiscent of those experienced in the past.

Applying Burn Analysis

- Historical weather data are cleaned and de-trended - Done
- Determine the slope of the payoff diagram - Done
- Determine index value – hypothetical payoffs for each year - Refer Excel Sheet
- Calculate payoff average to get:

$$\text{Pure Premium} = \left\{\frac{1}{n}\right\} * \sum_{i=1}^{n} x_n$$

  - Where n = number of years; X = Payout during year n

Applying Burn Analysis

- For the Pure Premium Obtained:
  - No discount rate has been used – Short term business
  - Contingency margin has to be added
  - A loading for expenses, Commission and Profit has to be added to obtain:
- The Office Premium

Numerical Integration

- The Motivation: To calculate an approximate solution to a definite integral.
- The definite integral we need to approximate is:
  - Pure Premium = $\int_{x=0}^{max} f(x)y(x)dx$

    x = Rainfall values

    f(x) = pdf of the fitted distribution

    y(x) = Payout for x mm of Rainfall
- Consider this as the product of the payout and the probability of the payout, summed over all the possibilities of rainfall.

Numerical Integration

- Steps involved:
  - Fit a Probability Density Function to the rainfall data.
    - Software that can do this: Easy Fit, R, Matlab etc.
  - Validate the best fit using Statistical tests such as Chi-Square, Kolmogorov-Smirnov and Anderson-Darling.
  - Obtain the Payout Structure.
  - Generate the PDF values for each value of rainfall possible in the time period
  - Obtain the Pure Premium by Numerically Integrating the Product of the Payout and the PDF values for each value of the Rainfall.

Numerical Integration

- We apply the following formula:
  - Pure Premium = $\int_{x=0}^{max} f(x)y(x)dx$
  - Which approximates to $\sum_{x=0}^{max} f(x)y(x)$

    Where:

    x = Rainfall values in increments of 1mm

    f(x) = pdf of the fitted distribution

    y(x) = Payout for x mm of Rainfall

  Refer Excel Sheet

Premium Loading

- Pure Premium to Office Premium
  - A loading for Profit, Expenses and Commission has to be made.
  - Expenses have to consider the cost of acquiring the business. This includes farmer awareness campaigns necessary for selling the product. To be able to incorporate this into the structure the future sales targets for each station have to be considered.
  - An Additional loading for contingencies is also added.
  - A loading for contingencies can be added by considering the standard deviation of the payout over the weather variable.
  - The sum of all the above gives us the Office Premium.

Example Policy

- If a farmer is willing to pay Rs 300 as premium per month then:
  - Sum insured is : Rs 3728 p.m
  - Minimum payout : Rs 372.8 p.m
  - Payout per unit: Rs 41.94

  - If the cumulative rainfall is 70mm then the payout is calculated as :

    372.8 + (100-70)*41.94 = 1631
  - If cumulative rainfall falls below 20mm then payout is:

    372.8+(80*41.94) = Rs 3728

Challenges

- Farmer Awareness
- Data Collection
- Reducing Basis Risk
- Affordability of Premium Rates
- Is there a need for a new type of Insurance?
- Dependence on weather station

Contact

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