The Design of Index-based Flood Insurance

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Workshop on "Enhancing the benefits of Remote Sensing Data and Flood Hazard Modelling in Index-based Flood Insurance(IBFI)"

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Contents

Farm Management Group

Team

- Head: Prof. Dr. Martin Odening
- Researchers: Dr. Matthias Ritter, Dr. Günter Filler, Dr. Zhiwei Shen
- Research Expertise: Risk management, especially climate risks, Investment and finance, Structural change in Agriculture

Related Research Projects and Publications

- Weather Risk Management (DFG), INKA-BB: insurance and climate change
  - Systemic Weather Risk and Crop Insurance: The Case of China. (Journal of Risk and Insurance)
  - Management of Climate Risks in Agriculture (Applied Economics)
  - Pricing Rainfall Futures at the CME. (Journal of Banking and Finance)
  - Can Expert Knowledge Compensate for Data Scarcity in Crop Insurance Pricing? (ERAE)
- Risk Management Tools for Wind Power Industry
  - Designing an Index for Assessing Wind Energy Potential. (Renewable Energy)

Weather Risk

Germany 2013

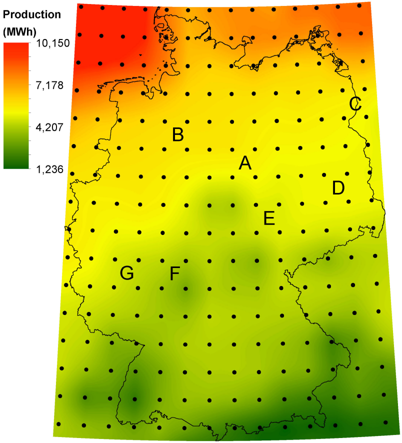
USA 2012

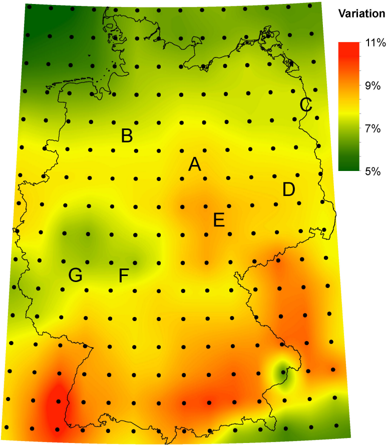
Rainfall Index Insurance

Table : Rainfall insurance for wheat producers in Brandenburg, Germany (ha)

	Option 1	Option 2
Rainfall index	Cumulative rainfall	Rainfall deficit
Accumulation	June	April-June
Calculation	$I^c = \sum_{t=1}^{30} R_t$	$I^d = \sum_{\tau=1}^{13} \min(0, \sum_{t=(\tau-1)\cdot 7+1}^{\tau\cdot 7} R_t - 7.4)$
Strike level S	144.3mm	-29.4mm
Tick size V	1.4€/ index point	13.5€/ index point
Payoff P	$\max(144.3 - I^c, 0) \cdot 1.4$	$\max(-29.4 - I^d, 0) \cdot 13.5$

Wind Index


Production
(MWh)
10,150
7,178
4,207
1,236
A
B
C
D
E
F
G


Variation
11%
9%
7%
5%
A
B
C
D
E
F
G

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Agricultural Insurance Products

Agricultural Insurance Products

- **Indemnity-based Insurance**
  - Named Peril Crop Insurance: Hail, Fire
  - Multiple Peril Crop Insurance (MPCI)
- **Index-based Insurance**
  - Weather-index Insurance
  - Area Yield Insurance
  - Price Index Insurance
  - Revenue Insurance (price$\times$yield)

Indemnity-based Insurance

Concept: Indemnity payments are based upon actual losses incurred.

Named peril crop insurance: Hail Insurance

- Perils: hail, fire (suited to localized, independent perils)
- Measure % damage in field; pre-agreed sum insured; operated in private sector; generally unsubsidised.
- Benefits: transparent loss assessment, manageable adverse selection and moral hazard
- Challenges: individual loss assessment; assessment cost in small farmers; not suited to complex perils.

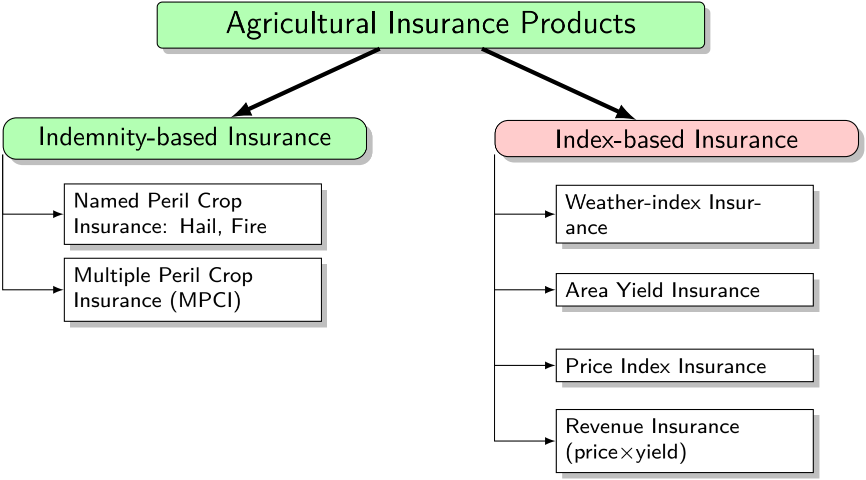
Indemnity-based Insurance

Concept: Indemnity payments are based upon actual losses incurred .

Multiple peril crop insurance

- Perils: a wide list of perils
- Measure yield loss compared to a % of average yield; highly subsidised; public-private-partnership (PPP).
- Benefits: easy to understand; limited technical adaptation required for different crops; indemnifies each farmer based on yield.
- Challenges: individual farmer loss assessment; adverse selection and moral hazard; poor data for yield history; high administrative cost; not suited where farms are small.

Agricultural Insurance Products



Index-based Insurance

Concept: Indemnity payments are based on objectively observable indices.

Weather-index Insurance

- Perils: rainfall deficit and excess; high or low temperatures
- Payouts based on weather station measurement
- No adverse selection and moral hazard; no individual loss adjustment; transparent, objective data
- Challenge: Basis risk; setting up index is complex; need good meteorological and agronomic data as well as crop modelling;

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Index-based Flood Insurance

The index insurance framework:

- Find an flood index I: cumulative rainfall, inundated area, flood duration, depths, water level (e.g. Sirajganj flood insurance) or combined index.
- Relation between crop yield and index

$$y = g(I) + \epsilon \tag{1}$$

y: crop yields; $g(\cdot)$: a function estimating the relation between yield and index; ϵ: error term indicating the basis risk.

- Payoff function

$$P(I) = V \cdot max\{0, S - I\} \tag{2}$$

I: index; P: insurance payout; S: strike level; V: tick size.

Design Index-based Flood Insurance

Estimating yield-index relation $g(\cdot)$

- Index form:
  - Single index: cumulative rainfall or excessive water level
  - Combined or transformed index to best fit the yield; e.g.,

$$\text{Weather-Yield} \quad Y_{corn} = \alpha_0 + \alpha_1 \mathbf{R} + \alpha_2 \mathbf{T} + \alpha_3 \mathbf{R}^2 + \alpha_4 \mathbf{T}^2 + \alpha_5 \mathbf{RT} + \epsilon$$

$$\text{Wind speed-Wind power} \quad f(WS; a, b, c, d, g) = d + \frac{a - d}{(1 + (\frac{WS}{c})^b)^g} + \epsilon$$

- Estimation technique
  - Standard Ordinary Least Squares
  - Bayesian estimation
  - Extreme theory e.g., quantile regression

Design Index-based Flood Insurance

Modelling the index $I \rightarrow$ Pricing the index insurance

The distribution of the index I is crucial to the assessment of insurance product. Its distribution influences the revenue distribution through the payoffs and also determines the cost of insurance. i.e., the price (F).

- Burn Analysis $F = exp(-r \cdot T) \cdot [\frac{1}{n} \cdot \sum_{t=1}^{n} P(I_t)]$
  $\rightarrow$ based on empirical distribution of index
- Index Value Simulation Statistical model for index
  $\rightarrow$ Parameters of distribution can be estimated from historical data
  $\rightarrow$ Index are randomly drawn to determine the price.
- Daily Value Simulation
  $\rightarrow$ A statistical model for stochastic process of the underlying variable (e.g. daily rainfall or water level)

Rainfall Index Insurance

Rainfall index insurance for grain producers in Northeast Germany:

- Specification of Rainfall Index:

  Rainfall sum:

$$I^c = \sum_{t=1}^{T} R_t$$

  Rainfall deficit:

$$I^d = \sum_{t=1}^{T} \min(0, \sum_{\tau=(t-1)\cdot s+1}^{\tau \cdot s} R_t - R^{\min})$$

  This index measures the shortfall of the rainfall sum in an $s-$days relative to a reference level $R^{\min}$.

Rainfall Index Insurance

- Estimation of Yield-index Relation $g(\cdot)$

  A linear-limitational (Leontief) production function to specify the relationship between rainfall index and wheat yield:

$$g(I) = \begin{cases} a_0 + a_1 \cdot I + \epsilon & \text{if } I < a_2 \\ a_3 + \epsilon & \text{Otherwise} \end{cases}, \qquad \epsilon \sim N(0, \sigma_\epsilon)$$

- Maximum likelihood estimation to determine the parameter estimates. Best fit (highest R^2) leads to favour rainfall deficit index for April to June.

Rainfall Index Insurance

- Pricing index
  - Burn analysis (historical empirical data)
  - Index value simulation: Daily rainfall model

$$R_t = \underbrace{r_t}_{\text{amount}} \cdot \underbrace{X_t}_{\text{occurance}}$$

$$X_t = \begin{cases} 0 & \text{if no rain} \\ 1 & \text{if rain} \end{cases}$$

Transition probabilities:

$$p_t^{01} = \Pr\{X_t = 1 | X_{t-1} = 0\}$$
$$p_t^{11} = \Pr\{X_t = 1 | X_{t-1} = 1\}$$

Rainfall amount r_t follows mixed exponential distribution:

$$f[r_t] = \frac{\alpha_t}{\beta_t} \exp[\frac{-r_t}{\beta_t}] + \frac{1-\alpha_t}{\gamma_t} \exp[\frac{-r_t}{\gamma_t}]$$

Diagram of Pricing Index-based Flood Insurance

Data
- Historical flood damage, crop yield data and flood hazard parameter index

Relationship
- Regress crop yields with flood hazard parameter index

Flood Index
- Based on relationship, derive flood index representing crop yields properly

Parameter Estimation
- Determination of model and distribution type of flood index
  -Bayesian estimation for data scarcity -Quantile estimation for extremes
  -Multivariate distribution for systemic risk

Simulation
- Simulated flood index from determined flood index model

Insurance Premium
- Determine trigger value and calculate insurance premium

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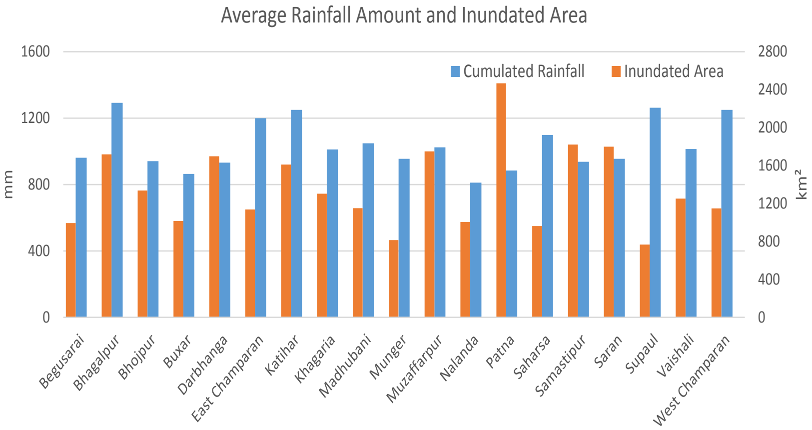
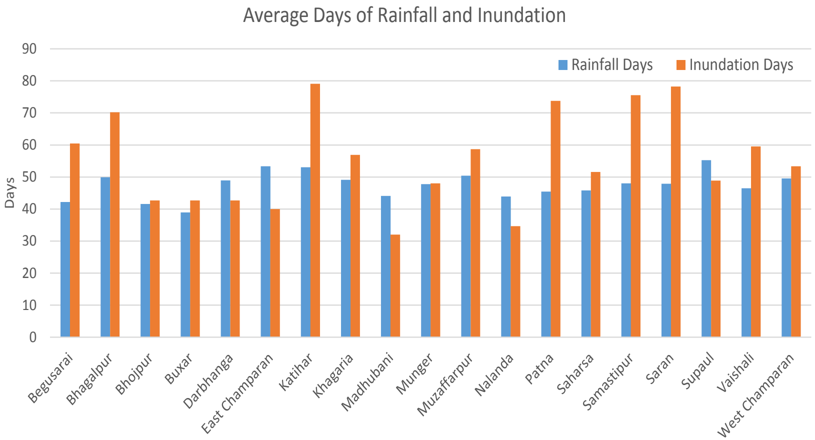
Exposure of Floods



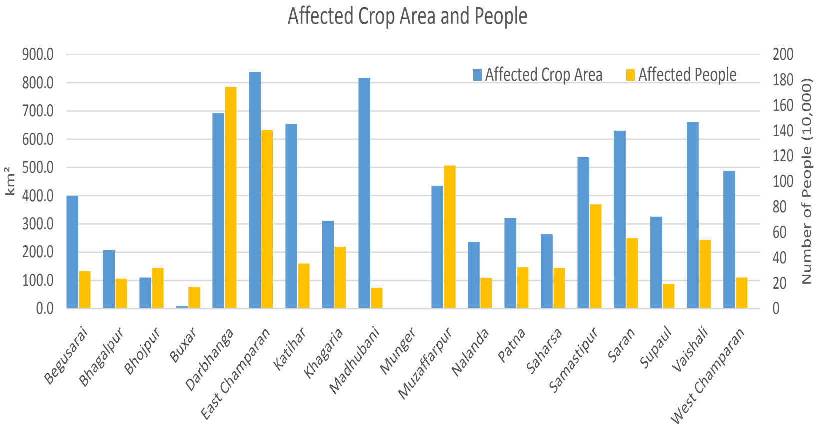
C. Rainfall	Bhagalpur, East Cham., Katihar, Supaul, and West Cham.
I. Area	Patna, Samastipur, Saran, Muzaffarpur, Bhagalpur
Both	Muzaffarpur, Bhagalpur

Exposure of Floods



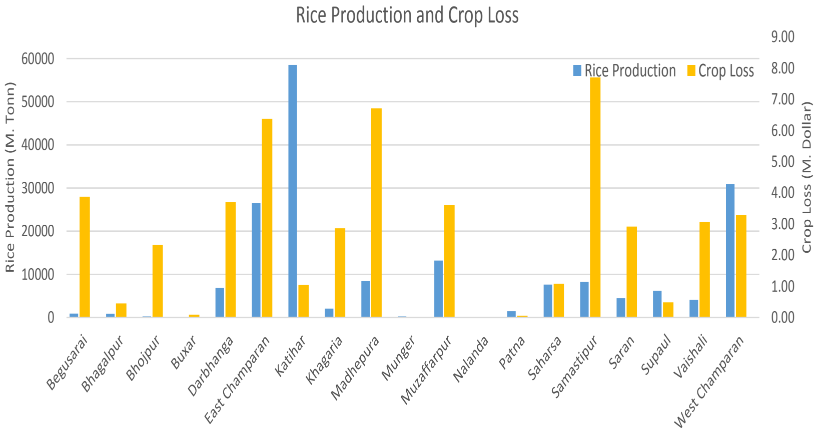
Rainfall Days	No significant difference; East Cham., Katihar, Supaul
Inundation Days	Katihar, Patna, Samastipur, Saran, Bhagalpur
Both	Katihar

Potential Insurance Demand



Affected Crop Area	Madhubani, East Cham., Darbhanga, Katihar, Vaishali
Affected People	Darbhanga, East Cham., Muzaffarpur, Samastipur
Both	Darbhanga, East Cham.

Potential Insurance Demand



Rice Production	Katihar, East Cham., West Cham., Muzaffarpur
Crop Loss	Samastipur, Madhepura, East Cham., Muzaffarpur, Darbhanga,
Both	East Cham., West Cham., Muzaffarpur

Identification of Pilot Location

Potential pilot locations: Muzaffarpur, East Champaran, Katihar,
The following reasons:

- High exposure to flood risk
- High potential rice insurance demand given high rice production
- Better data quality
- Accessibility to farmers and fields

Table : Flood exposure and crop losses in flood years

	Muzaffarpur		East Champaran		Katihar	
	mean	std.	mean	std.	mean	std.
R. Area (km^2)	1070.7	338.6	1237.5	297.2	1277.5	253.5
I. Area (km^2)	1750.2	1530.4	1138	702.8	1611.2	367.2
Crop loss (M. Rs.)	216.9	343.6	382.5	254.9	62.5	61.6

Conclusion

- Agricultural Insurance Products
  → Indemnity-based Insurance
  → *Index-based Insurance* for special risk and small households

- Design of Index-based Flood Insurance
  → Estimating yield-index relation
  → Modelling the index

- Identification of Pilot Location
  → *Muzaffarpur*, East Champaran, Katihar

The End

Questions? Comments?

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