turning knowledge into practice

Crop Insurance and Mitigation of Impacts from Climate Variability

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Climate Change Science Program SAP 4.3 Report

- U.S. Climate Change Science Program (CCSP) conducted a comprehensive study titled, “The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States,” that examines the biological responses of several crops grown historically in the United States to increases in temperature, precipitation, CO2, and water availability (CCSP, 2008)
- Concludes that:
  - Climate changes – temperature increases, increasing CO2 levels, and altered patterns of precipitation – are already affecting U.S. water resources, agriculture, land resources, and biodiversity (very likely)
    - Forest fires, insect outbreaks, increasing precipitation, reduced snowpack in western US and earlier runoff, higher growth rates for crops and weeds, migration of plant and animal species
  - Climate change will continue to have significant effects on these resources over the next few decades and beyond (very likely)
    - Continued warming, temperature extremes beyond thresholds, changing runoff patterns in the western US
  - Many other stresses and disturbances are also affecting these resources (very likely)
- Assessment of potential impacts rather than a “scenario” (no GCM runs associated with this report)

Climate Impacts and Insurance

- Potential impacts of climate change on mean crop yields as well as yield variability
  - Production expected to become riskier
    - Adverse weather, pests
- Crop insurance is an important risk management tool for agriculture
- Effects on insurance program design under changing climate
  - Changing risk relative to historical experience
  - Financial exposure of private insurers and US government to catastrophic events

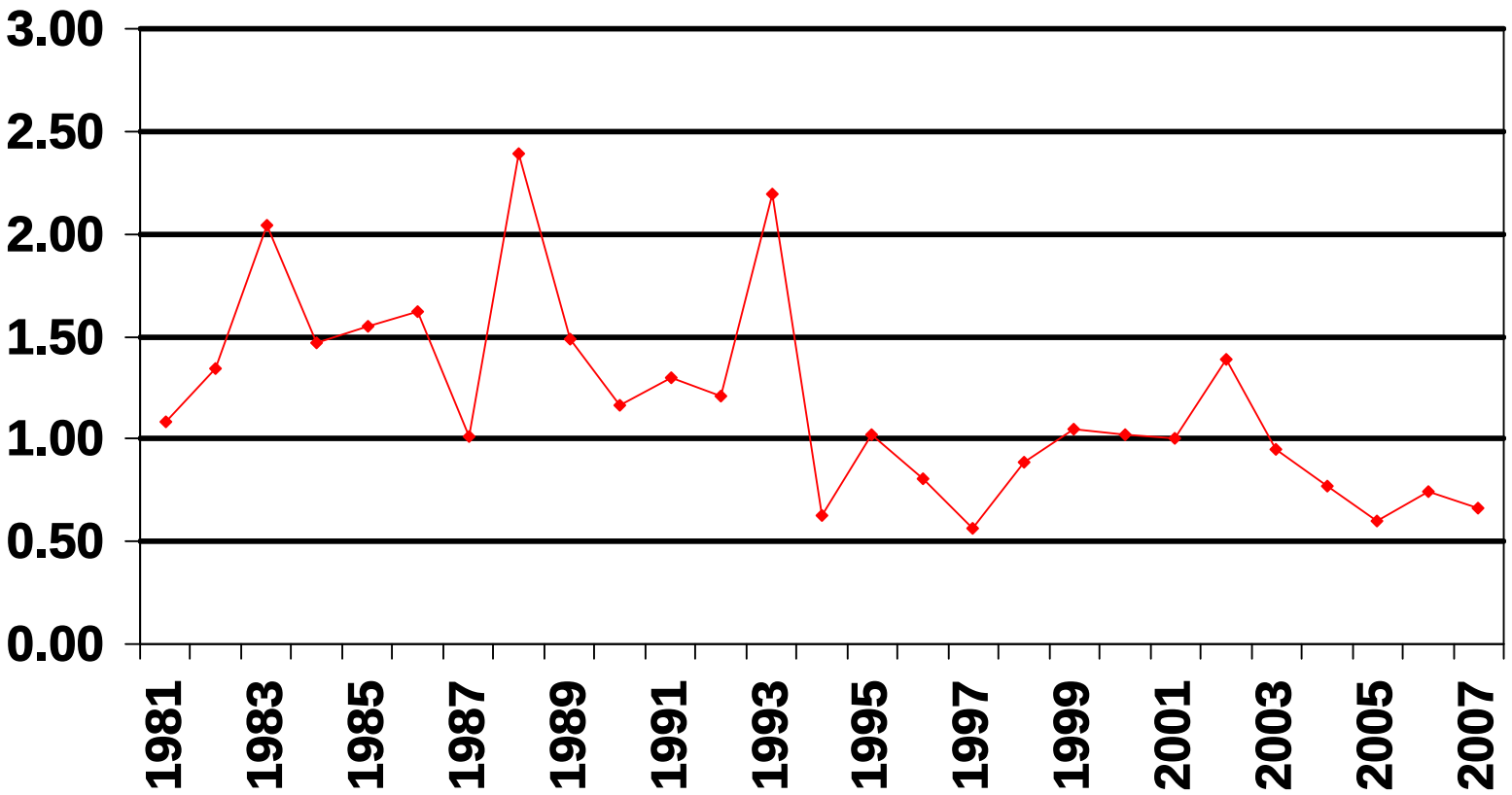
US Crop Insurance Program

- Annual enrollment prior to planting
- Coverage based on
  - Recent yield history
  - Price forecasts
  - Futures contracts
- Multiple-peril insurance, revenue and index based plans
- Premium rates based on coverage and risk
- Indemnity paid if index is triggered or the yield and/or revenue at end of season is below guarantee

Program Participation

2007 Crop Ranking by Liability		
Crop	***Liability ($ Mil.)***	***% of Total***
Corn	$31,256	46.8%
Soybeans	$11,440	17.1%
Wheat	$5,364	8.0%
Nursery	$4,019	6.0%
Cotton	$1,990	3.0%
FL Fruit Trees	$1,175	1.8%
Potatoes	$842	1.3%
Grain Sorghum	$760	1.1%
All Others	$9,983	14.9%
Total	$66,830	100.0%

Insurance Loss Experience, 1981-2007



Source: Erny (2008).

Public-Private Provision of Crop Insurance

- Private companies deliver insurance locally through a network of agents
- Federal Crop Insurance Corporation (FCIC) subsidizes policies and provides reinsurance for private companies
- Terms of reinsurance are established through the ***Standard Reinsurance Agreement (SRA)*** — a cooperative risk-sharing agreement between FCIC and private insurance companies

Crop Insurance Slang

- APH = Actual Production History (yield insurance)
- CAT = Catastrophic coverage (low cost, high deductible policy)
- CRC = Crop Revenue Coverage
- Coverage level = portion of yield or revenue insured
- Insurance product type
  - A class of insurance contracts, e.g. APH vs. CRC vs. CAT
- Insurance product
  - A contract with a specific coverage level, e.g. 65% APH vs. 70% APH etc.

Risk Sharing under the SRA

- Each policy can be assigned to one of three reinsurance funds
  - Commercial Fund
  - Developmental Fund
  - Assigned Risk Fund
- Commercial and Developmental funds are further subdivided into CAT, Revenue, and “Other Products” funds
- Premium cession limits (how much of total premiums can be assigned to a fund)
  - Limits for Assigned Risk Fund vary by state (25% to 75%)
  - No restrictions on Commercial or Developmental funds
- Once all policies are assigned, insurers
  - cede a portion of all premiums and liabilities to FCIC (proportional reinsurance)
  - share losses and gains on the retained portion of book of business with FCIC (non-proportional reinsurance)

Proportional Reinsurance

- An insurer completely transfers a portion of net premiums and associated liabilities to FCIC
- Retention requirements (how much the insurer has to keep on its balance)
  - Assigned Risk Fund — between 15% and 25% (depends on the state)
  - Developmental Fund — at least 35%
  - Commercial Fund — at least 50%
- ***Funds essentially operate on the state level***

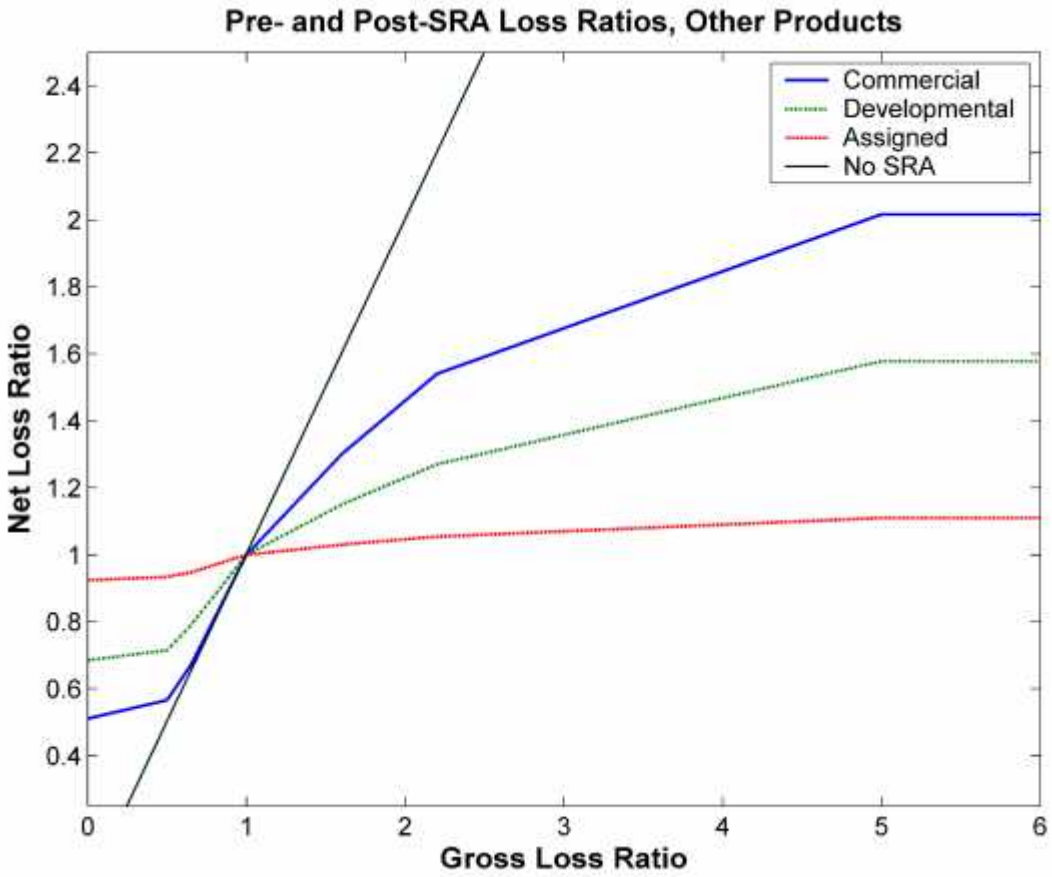
Non-proportional Reinsurance

- Applies to the portions of portfolios retained (not ceded under proportional reinsurance)
- Shares of losses and gains are determined based on the realized state-level *loss ratios* (indemnities paid divided by premiums collected)
  - the higher the loss ratio above 100%, the larger the portion of losses covered by FCIC
  - the lower the loss ratio below 100%, the larger the portion of gains claimed by FCIC

Schedules of Gains and Losses

	Gains			Losses		
Fund	CAT	Rev	Other	CAT	Rev	Other
	Loss Ratio 65% to 100%			*Loss Ratio 100% to 160%*		
COM	75.00%	94.00%	94.00%	50.00%	57.00%	50.00%
DEV	45.00%	60.00%	60.00%	25.00%	30.00%	25.00%
ARF		15.00%			5.00%	
	Loss Ratio 50% to 65%			*Loss Ratio 160% to 220%*		
COM	50.00%	70.00%	70.00%	40.00%	43.00%	40.00%
DEV	30.00%	50.00%	50.00%	20.00%	22.50%	20.00%
ARF		9.00%			4.00%	
	Loss Ratio less than 50%			*Loss Ratio 220% to 500%*		
COM	8.00%	11.00%	11.00%	17.00%	17.00%	17.00%
DEV	4.00%	6.00%	6.00%	11.00%	11.00%	11.00%
ARF		2.00%			2.00%	

How SRA Transforms Loss Ratios



Aspect ratio 2:1

EPIC Model

- Process-level agro-ecosystem model
- Has been used previously to simulate regional productivity of corn, soybeans, winter wheat, cotton, hay, and switchgrass for the U.S. at the 8-digit hydrologic unit scale
- Additional cropping systems were added to include sorghum, rice, barley, and potatoes for the appropriate regions
- Multiple soil types are represented within the 1,450 hydrologic units with agricultural production
- Modeling system is currently using baseline climatology for 1990-2000 with IPCC SRES scenario A1B
- Future projections incorporate GCM results from the Geophysics Fluid Dynamics Laboratory CM2.0 and CM2.1 models and the Canadian Center for Climate Modeling and Analysis CGCM model

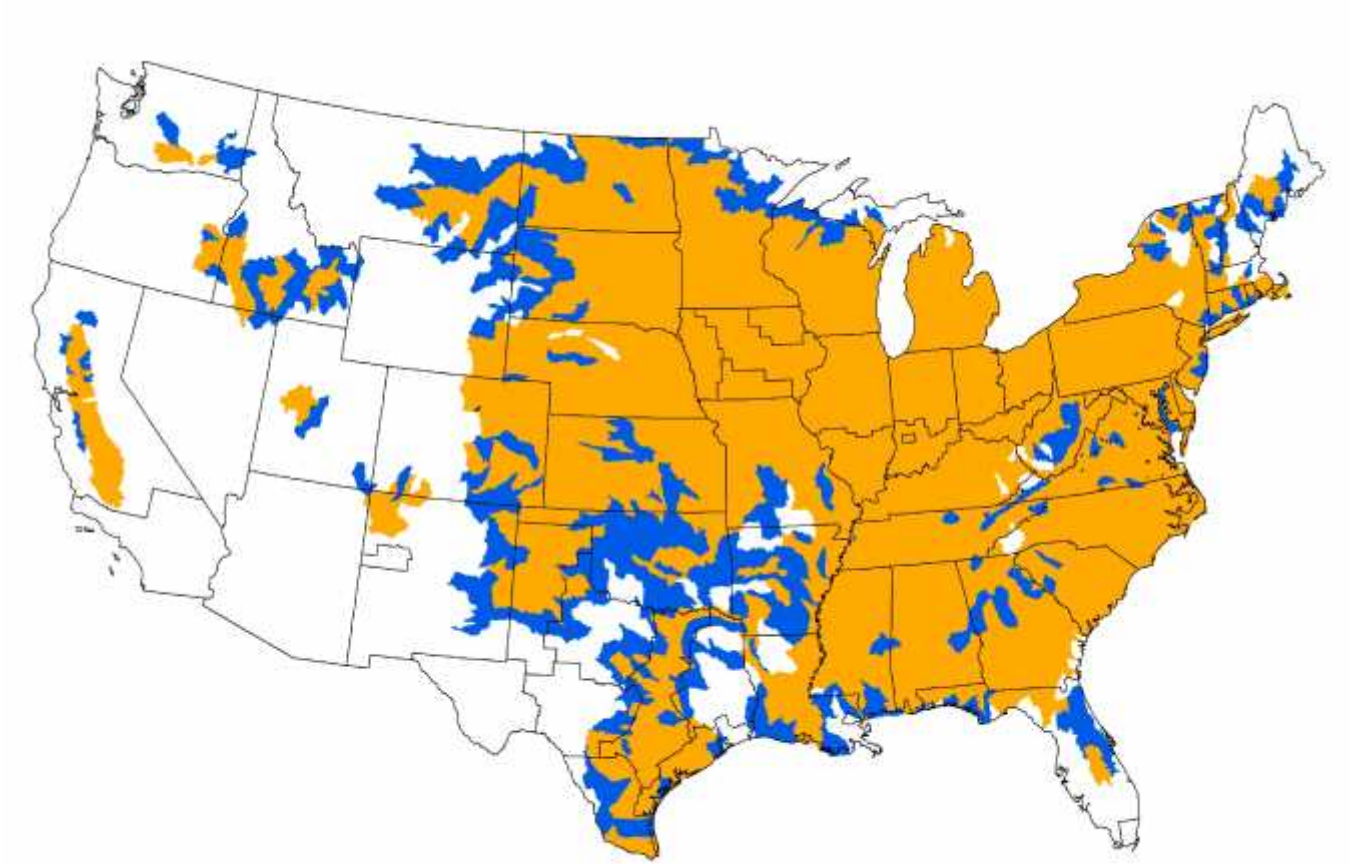
Crops Modeled in EPIC

- Crops being modeled in EPIC comprise about 83% of total US crop insurance liability based on 2008 data
  - cotton,
  - corn,
  - soybeans,
  - hay,
  - wheat,
  - sorghum,
  - rice,
  - barley, and
  - potatoes.

Examining Shifts in Production Regions

- Changes in yield distributions may alter production regions
- Areas where crops were modeled in EPIC were expanded outside recent historical range
  - Focused on suitable cropland areas in proximity to historical range
  - EPIC simulations of mean and variance of yield
- Equilibrium production is being simulated based on stochastic version of FASOM

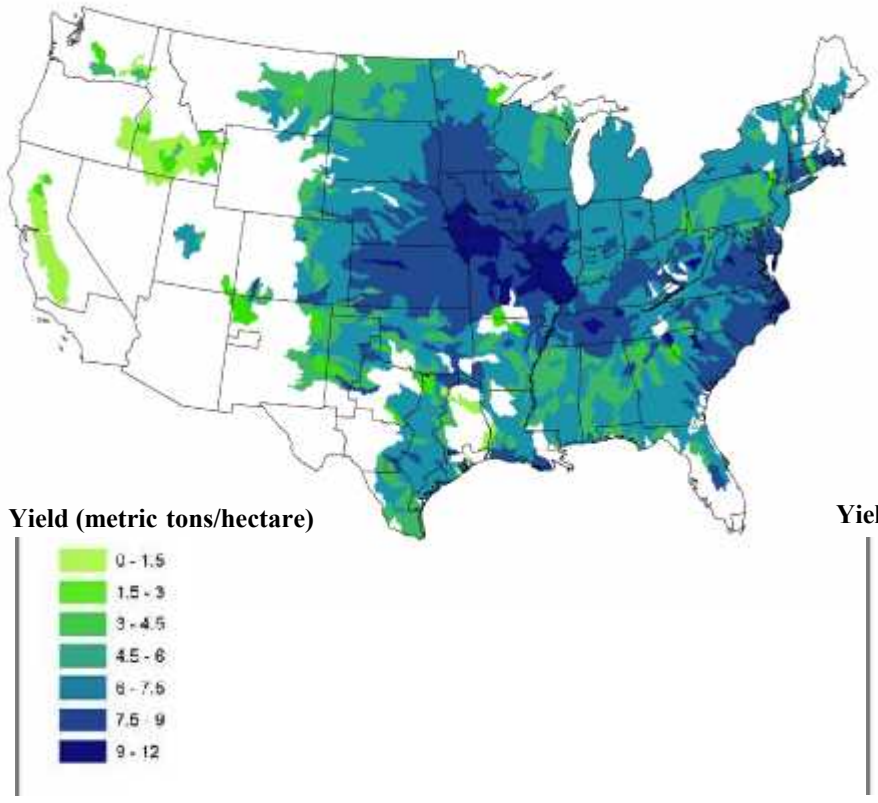
Current and Expanded Corn Range Modeled in EPIC



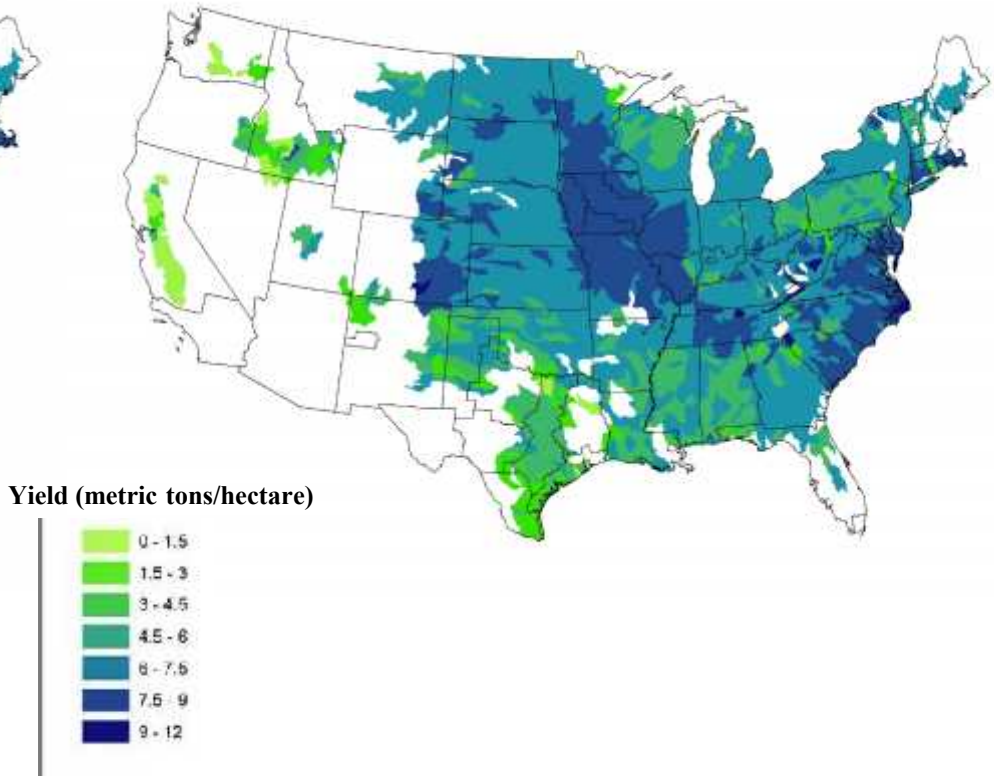
Note: Orange areas are current crop range included in database. Blue areas are the additional regions where potential crop production is being modeled to allow for shifts in cropping patterns under climate change scenarios, though actual production regions will depend on market outcomes modeled in FASOM..

Non-Irrigated Corn Yield – GFDL CM2.1

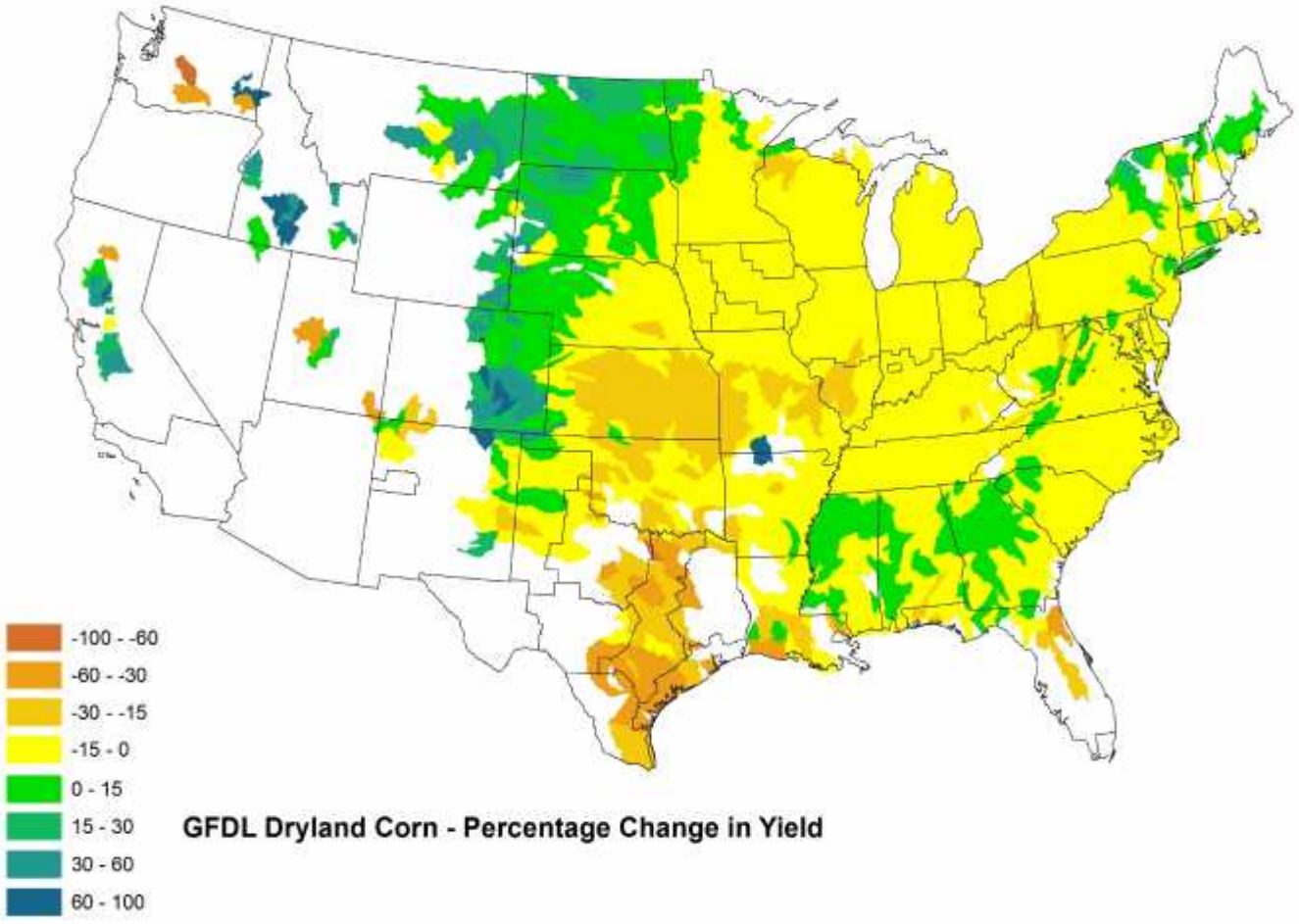
Baseline Climate1990-2000



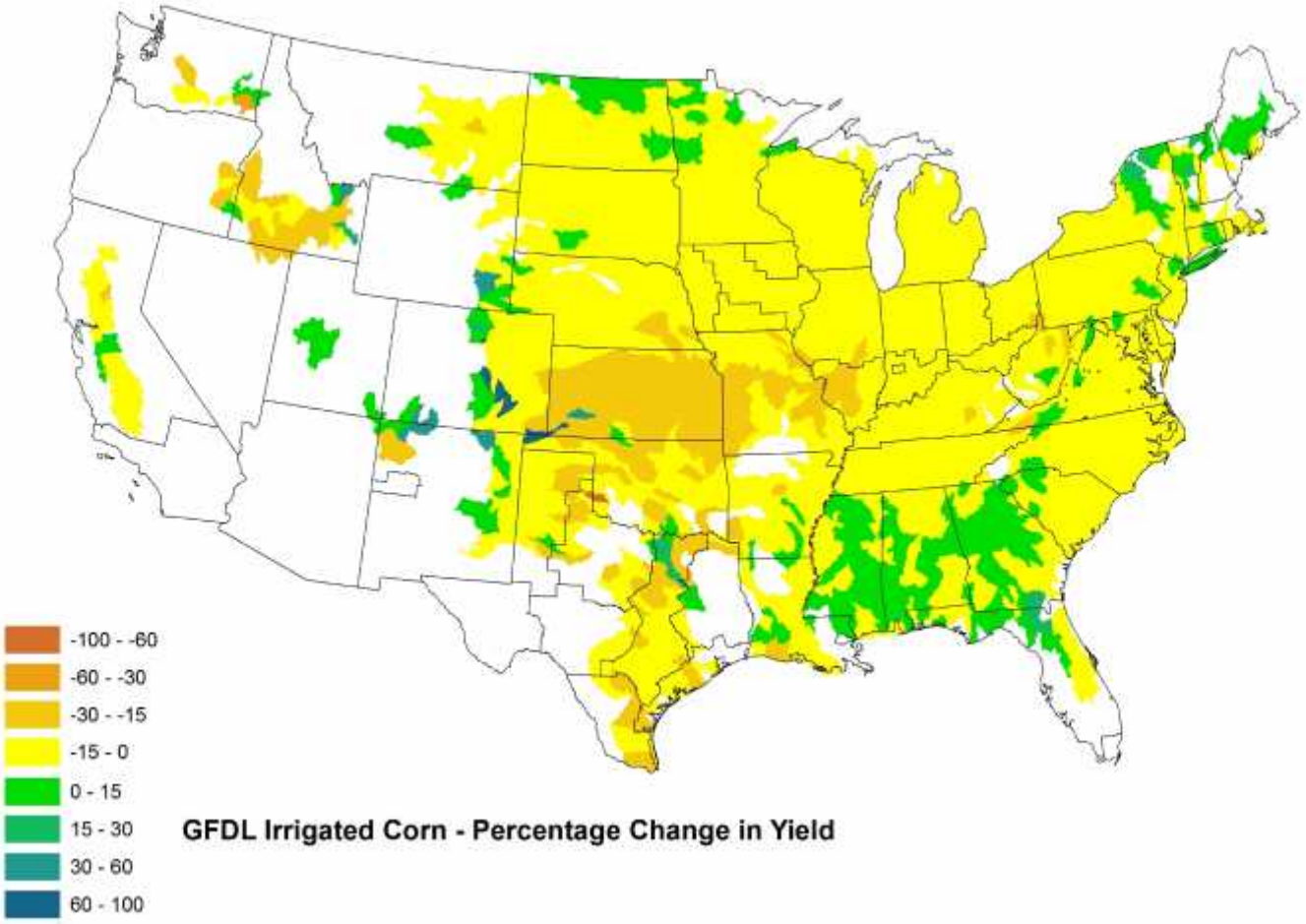
Scenario 2045-2055



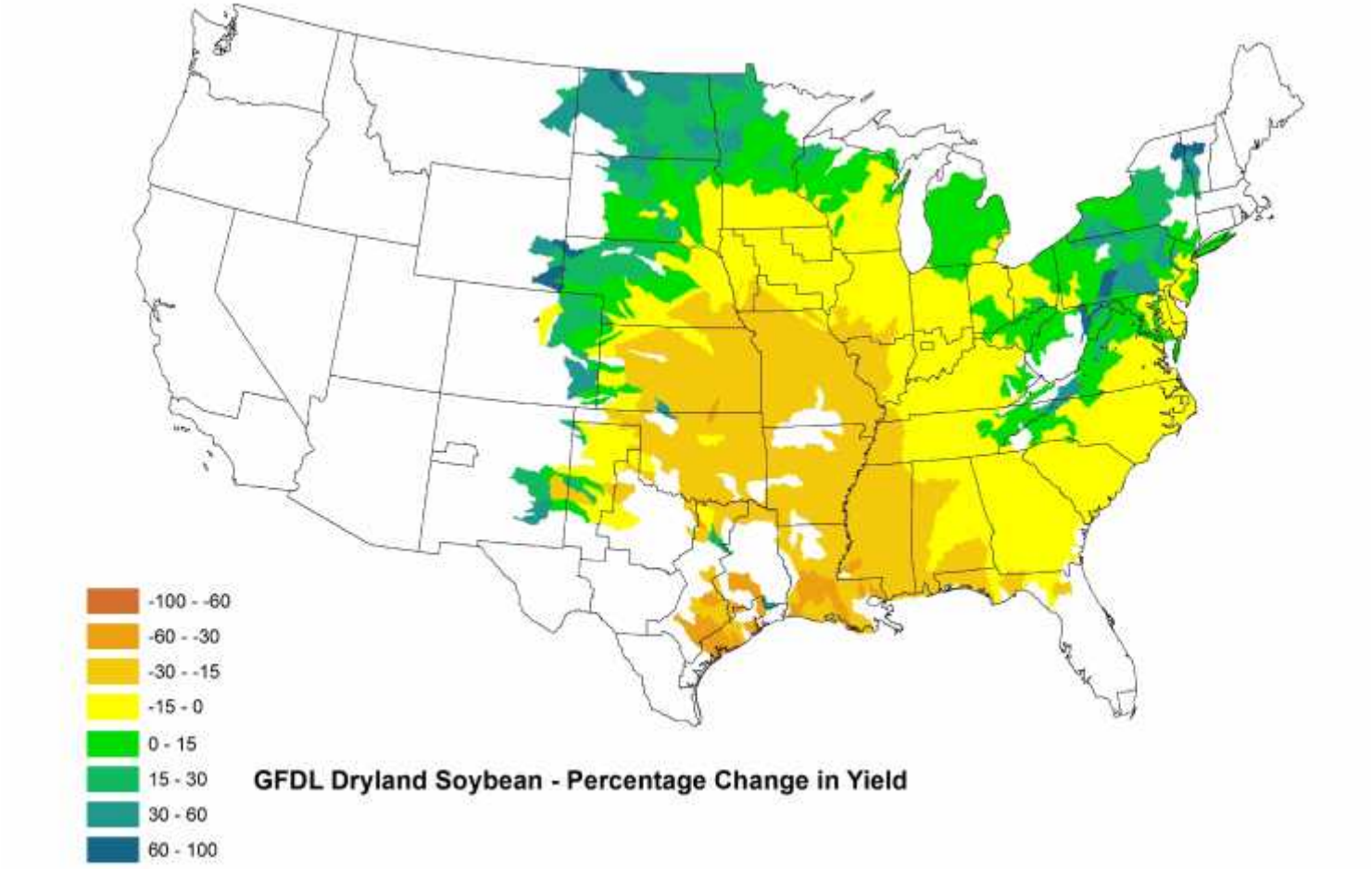
Percentage Change in Non-Irrigated Corn Yield for GFDL GCM



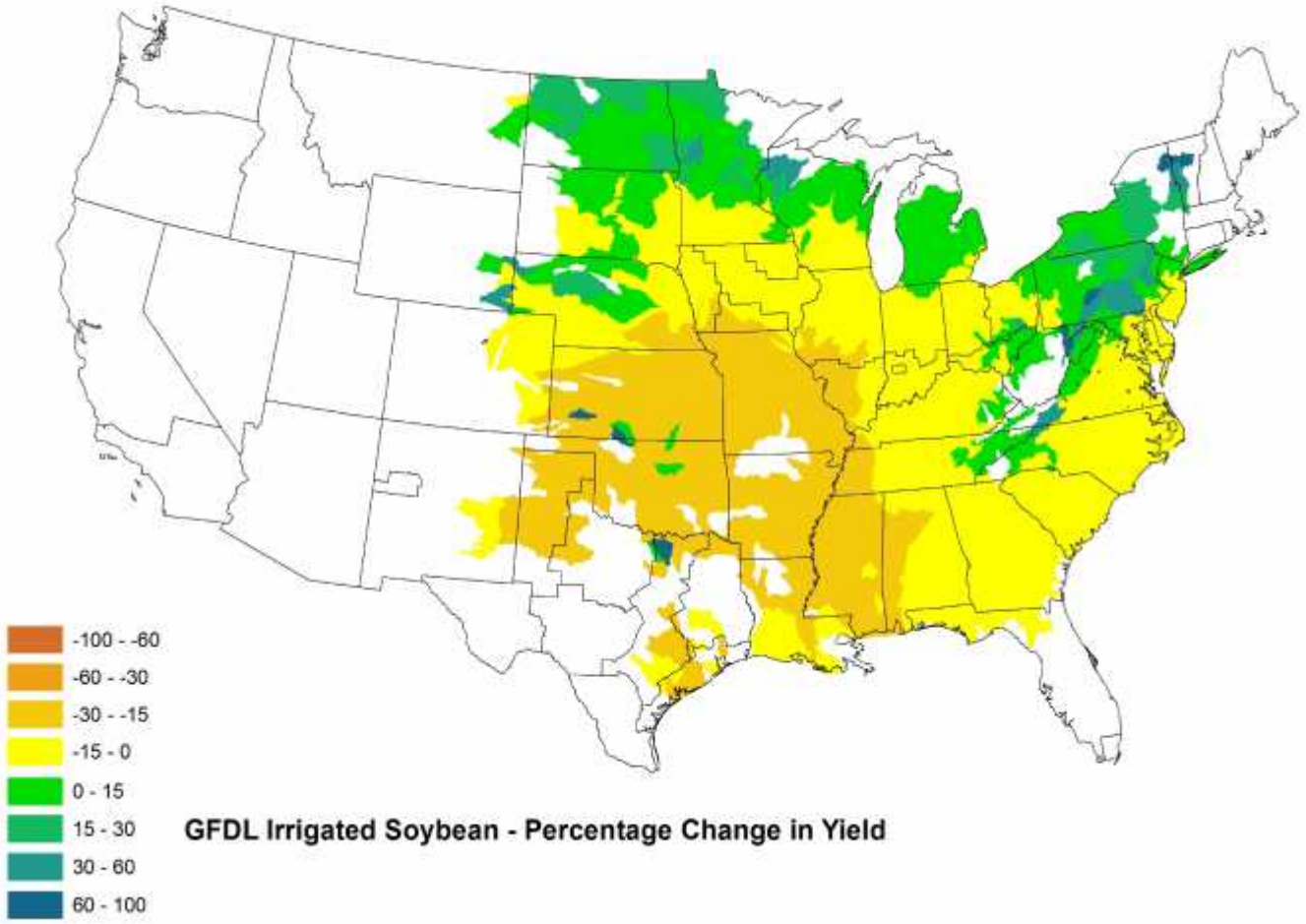
Percentage Change in Irrigated Corn Yield for GFDL GCM



Percentage Change in Non-Irrigated Soybean Yield for GFDL GCM



Percentage Change in Irrigated Soybean Yield for GFDL GCM



Stochastic FASOM

- Being used to model economic decisions and assess agricultural market outcomes under alternative scenarios with different yield distributions
  - Crop allocation decisions by crop and management categories based on the relative risk and returns to alternative cropping patterns under the yield distributions associated with the climate scenarios
    - % change in mean yield
    - % change in standard deviation of yield
  - Change in equilibrium commodity prices and regional distribution
- Equilibrium outcomes depend on relative changes for alternative crops within a region

Modeling Yield Distributions and Expected Losses

- Use the changes in yields simulated using EPIC in actuarial models of major crop insurance programs
- Incorporate information from FASOM on cropping patterns and equilibrium prices
- Will provide estimates of changes in the distribution of expected losses (probabilities and sizes or indemnities) under alternative climate scenarios

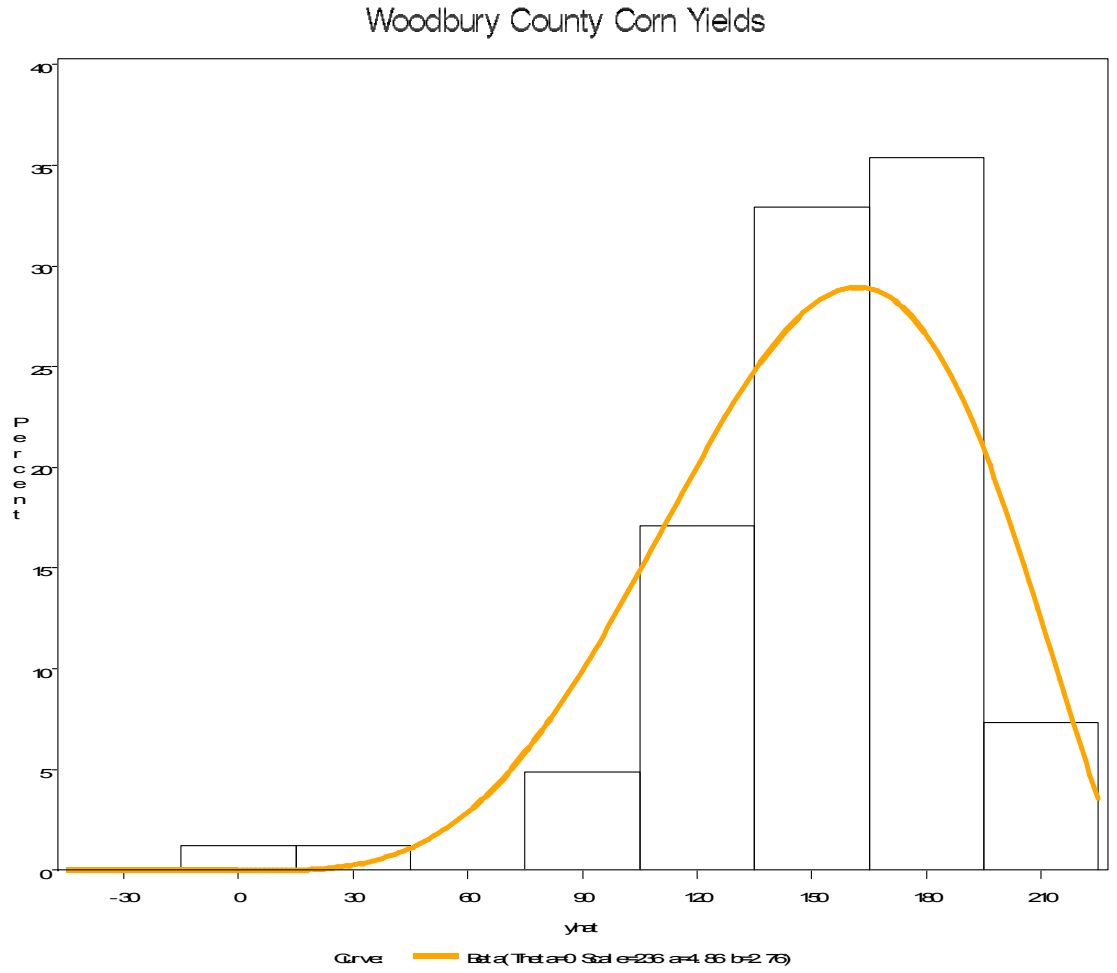
Yield Distributions

- Relying on county-level historical data from USDA NASS to obtain detrended baseline yields
- Fit beta distributions to these yields
  - $$f(y) = \frac{(y-a)^{\sim -1}(b-y)^{\ -1}}{B(\sim,\ )(b-a)^{\sim +\ -1}}$$
  - where α and β are shape parameters, *a* and *b* are the lower and upper bounds (respectively), *y* is the normalized detrended yield and B is the beta function

Price Distributions

- Analysis of revenue insurance requires estimation of price distributions and correlation between prices and yields
- Lognormal distribution fit to detrended prices
- Calculate correlation between price and yield and impose on draws

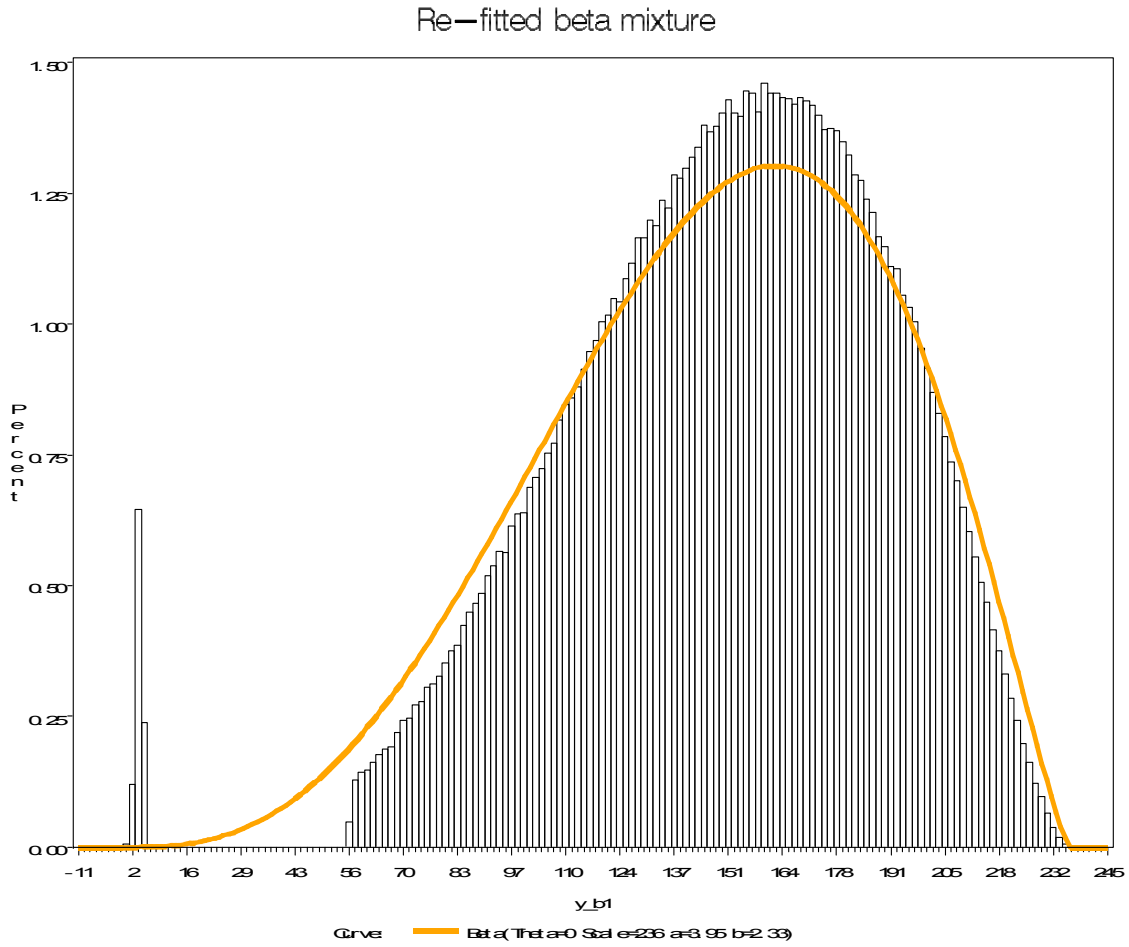
Example of Fitted Beta Distribution, Woodbury County, IA



Accounting for Extreme Events

- Using historical data implicitly assumes low frequency high loss events are reflected
- However, data series for some crops/regions may not be long enough to capture and probability of these events may change in the future
- Thus, we are also looking at adjustments to account for infrequent extreme losses
  - Little information to quantify these changes, so primarily using as sensitivity analyses

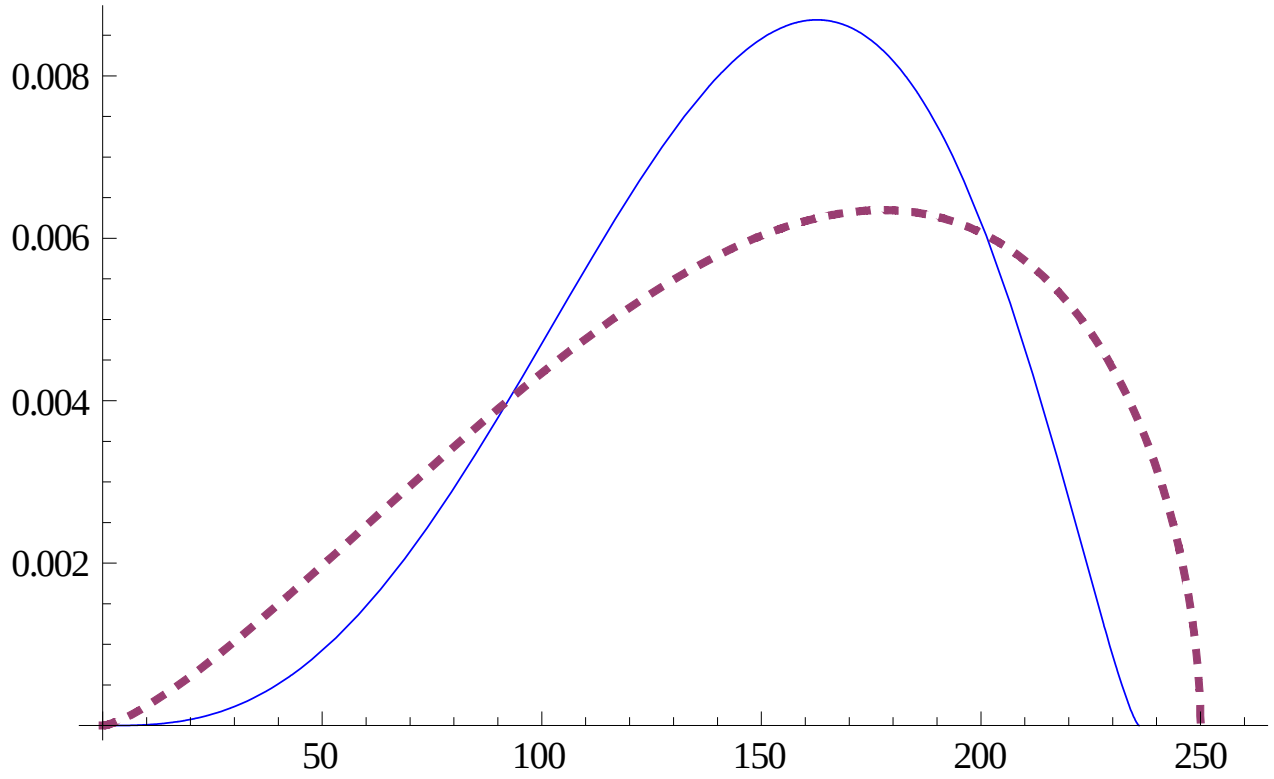
Example of a Re-Fitted Beta Distribution Accounting for Low Probability Disaster Outcomes, Woodbury County, IA



Summary Statistics of Expected Loss Costs for 2007 APH Corn in Woodbury County, IA without Climate Change (1 million yield draws)

Coverage Levels	Mean	St. Dev.	Min.	Max.
50%	0.0128	0.0664	0	0.9376
55%	0.0181	0.0783	0	0.9432
60%	0.0245	0.0906	0	0.9480
65%	0.0323	0.1033	0	0.9520
70%	0.0416	0.1160	0	0.9554
75%	0.0525	0.1286	0	0.9584
80%	0.0649	0.1408	0	0.9610
85%	0.0789	0.1526	0	0.9633

Shift in the Yield Distribution of Corn in Woodbury County, IA due to Climate Change



Summary Statistics of Expected Loss Costs for 2007 APH Corn in Woodbury County, IA with Climate Change (1 million yield draws)

Coverage Levels	Mean	St. Dev.	Min.	Max.
50%	0.0383	0.1282	0	0.9920
55%	0.0474	0.1414	0	0.9928
60%	0.0576	0.1541	0	0.9934
65%	0.0687	0.1664	0	0.9939
70%	0.0809	0.1781	0	0.9943
75%	0.0940	0.1891	0	0.9947
80%	0.1081	0.1994	0	0.9950
85%	0.1230	0.2088	0	0.9953

Summary

- In addition to changes in mean yields, changes in variability are important for farmer decisions and probability of losses
  - Could have increase in mean yield, but also increase in expected losses (changes in the lower tail of the distribution drive indemnities)
- Insurance can help farmers manage risk, but need for analysis of feasibility of offering coverage for certain crops/regions/coverage levels under climate change
- Adaptation is likely to have an important influence