# 17. Basis Risk and Effectiveness of Rainfall Index Insurance for Pasture, Rangeland, and Forage

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## Abstract/Summary

*Pasture, Rangeland, and Forage (PRF-RI) insurance coverage is a relatively new insurance plan for grazing and haying lands which uses a rainfall index for a large "grid" area as the basis for coverage. How well does the grid rainfall outcome track with a producer's own forage output? The potential for difference results in "basis risk," and this study takes an initial look at it for a set of locations. Using historical yield and rainfall data from two university-managed ranches, we measure basis risk of PRF-RI and use the estimated results to evaluate the effectiveness of PRF-RI. Because our dataset has relatively large number of variables compared to the number of observations, we use a method to estimate the relationships between yields and precipitation and yields and PRF indices and provide estimates on the degree of the basis risk of PRF-RI. Our estimates suggest that the overall basis risk of PRF-RI is about 90% of total pasture yield variation and about 6.7% of the basis risk is due to the difference between actual precipitation and PRF indices.*

# Basis Risk and Effectiveness of Rainfall Index Insurance for Pasture, Rangeland and Forage

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Risk and Profit Conference, 2017,
Kansas State University Alumni Center, August 17th





## Rainfall Index Insurance for Pasture, Rangeland and Forage (PRF-RI)

1. In 2007, the Risk Management Agency (RMA) launched a pilot program to provide insurance for pasture, rangeland, or forage acres.
2. RMA developed insurance based on rainfall and vegetation indices which would serve as proxy measures for forage yields (vegetation index program is no longer available) - we focus on "Rainfall Index Insurance"
3. PRF-RI is an index insurance: Basis risk exists.

# Research Questions

1. How does the PRF-RI program work?
2. How large is the basis risk for the PRF-RI program?
3. How much of the basis risk can be reduced?





# Outline

## Pastureland and PRF Participation Rates

1. In 2012, pastureland acreage was about 456 million acres in the U.S. - about 16 million acres were in Kansas (2012 Census of Agriculture).
2. Low participation rates: In 2016, about 52 million acres (about 11% of total pastureland) enrolled in the U.S. - about 0.8 million acres in Kansas.





## Precipitation, Rainfall Index Insurance and Forage Yields

1. Relationship between monthly precipitation and forage yields: Precipitation in April to May (Lee and Boe 2005), April to June (Smart et al. 2005) and May to July (Smoliak 1986) explain forage yields.
2. Rainfall Index Insurance in US
   1. Optimal choice of PRF-RI: Diersen et al. (2015) suggests May-June interval would have highest weights to minimize the variance of producers' returns.
   2. Effectiveness of RI Annual Forage Program (Maples et al. 2016)
   3. Impacts on farmland values (Ifft et al. 2014)

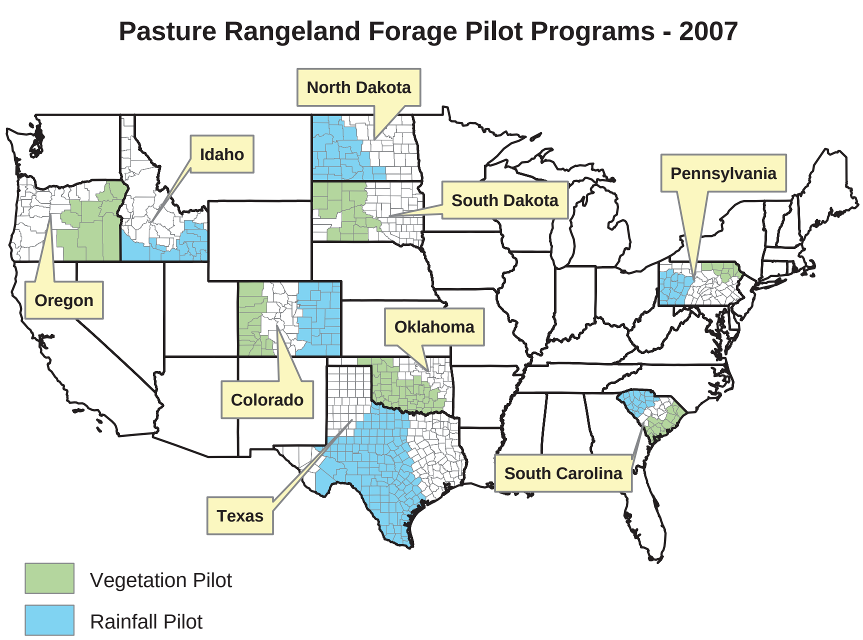
# PRF Programs: Rainfall and Vegetation Pilots

1. In 2007, the PRF pilots, rainfall and vegetation pilots, were offered in 9 states.
2. Both Rainfall Index pilot (PRF-RI) and Vegetation Index pilot (PRF-VI) do not insure individual yields: "Index"-based and "area"-based - there exists "basis" risk.
3. Similar to the other crop insurance programs, premium is highly subsidized.





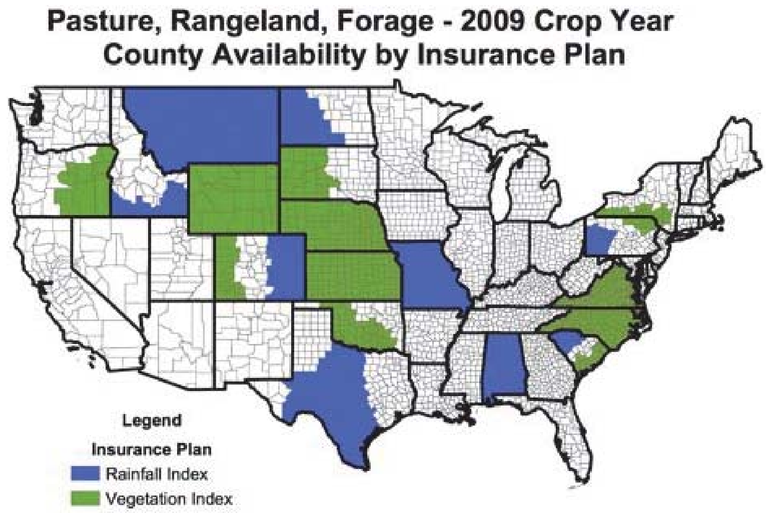
# PRF Pilots in 2007




Source: RMA, USDA

# PRF Pilots in 2009

In 2009, PRF was offered to Kansas farms for the first time (VI).



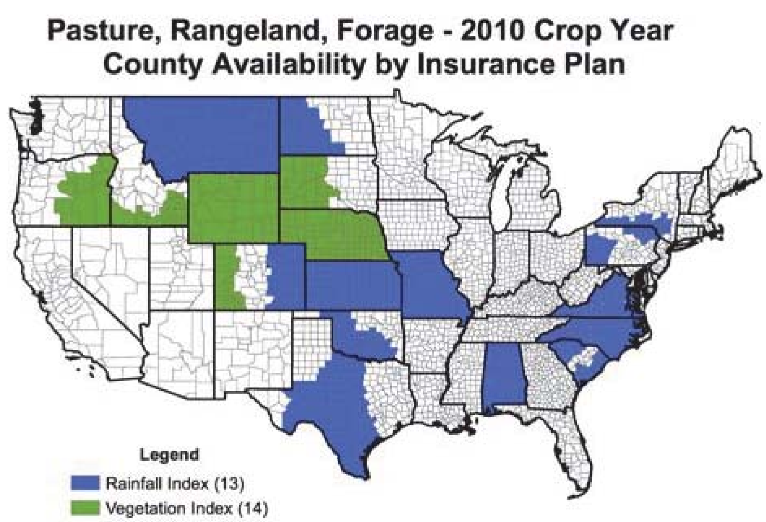

Source: RMA, USDA





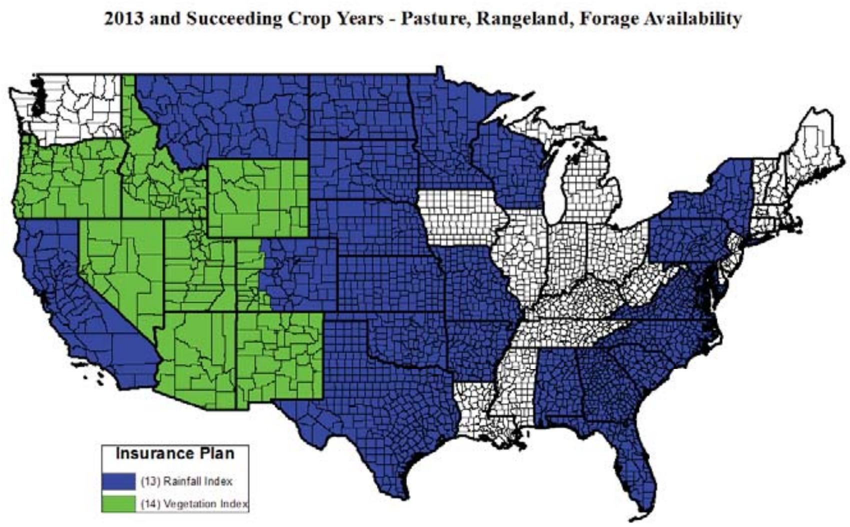
# PRF Pilots in 2010

Starting 2010, PRF-RI has been offered instead of VI.




Source: RMA, USDA

# PRF Pilots in 2013



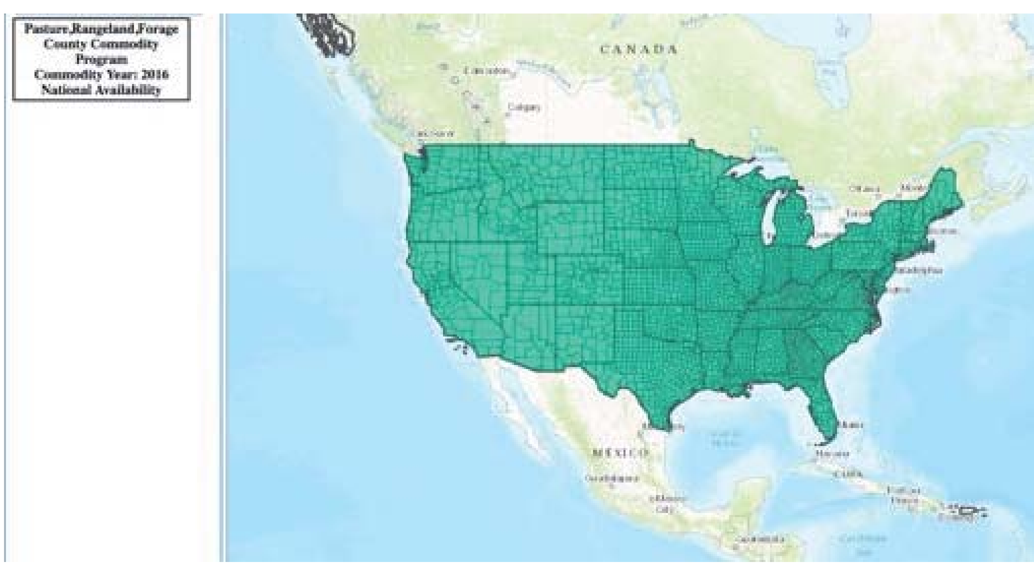

Source: RMA, USDA





# Currently, only RI program is being offered (starting 2016)

All contiguous 48 states are eligible.




Source: RMA, USDA

## How PRF-RI Works

1. An operator chooses coverage level (70%-90%), which is a share of historical average rainfall for the grid that operator is located, and assigns dollars to several 2-month intervals to be covered by PRF-RI.
2. If the rainfall index falls below the guarantee for some 2-month intervals the operator chose, the operator gets paid proportional to the value he assigned to those intervals.
3. Farms pay a portion of fair premium: Premium is highly subsidized (ranges from 51 to 59%).

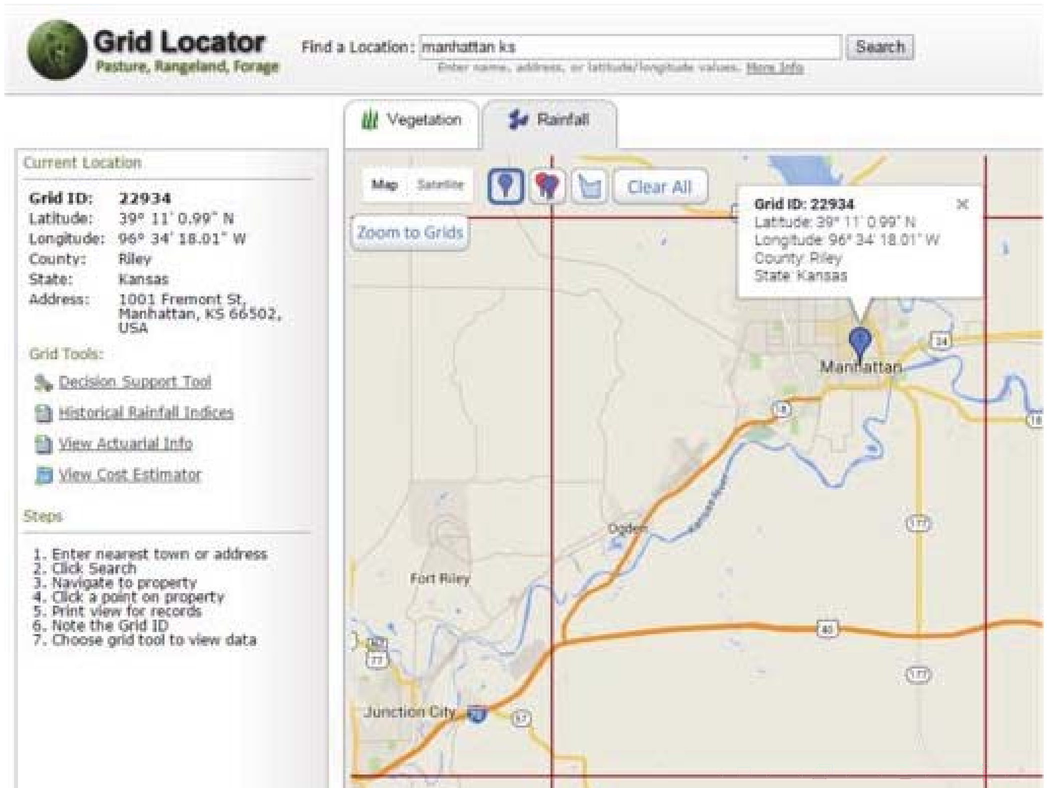




## PRF index

1. PRF indices for each 2-month interval are created based on precipitation at NOAA weather stations.
2. For each grid, indices are computed based on the weighted average of precipitation from four nearest weather stations to center of each grid.
3. If the indices fall below guaranteed level measured as a share of historical average, insurance indemnity payment triggeres.

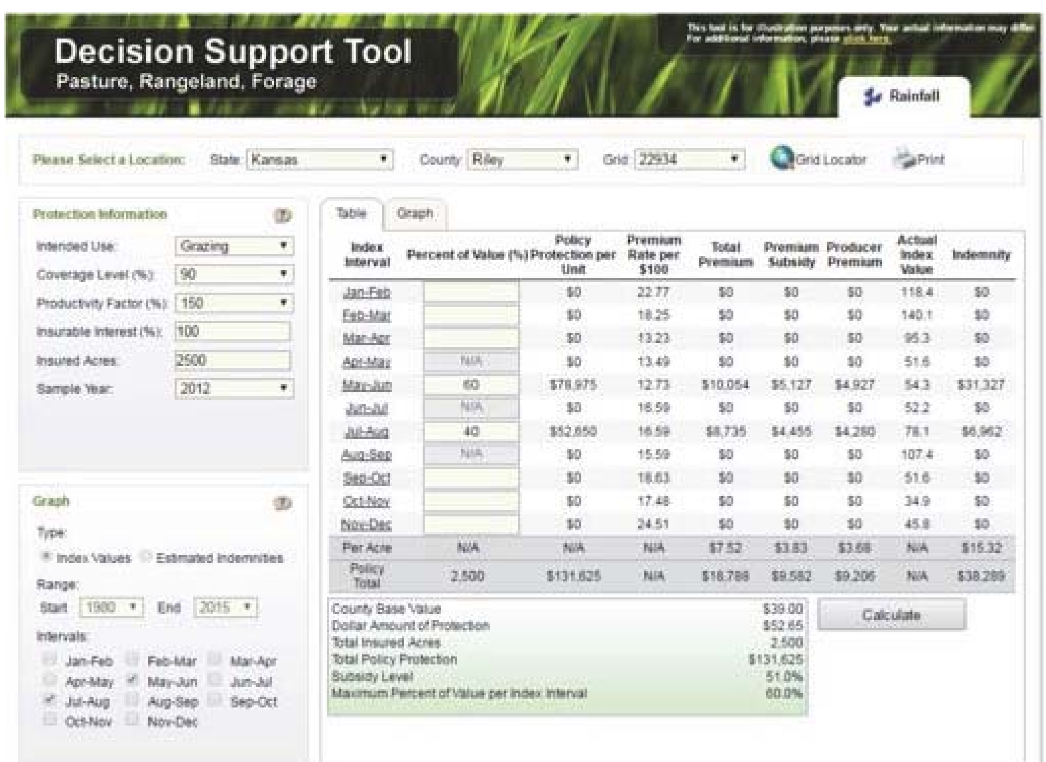
# Grid Locator







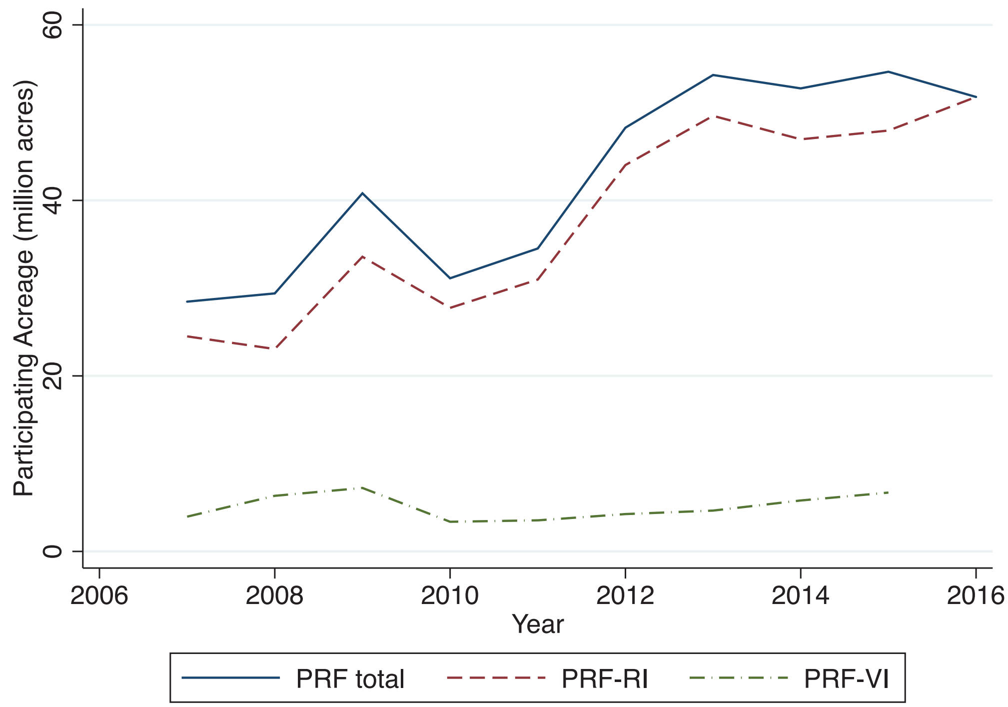

# Decision Support Tool




| Index Interval | Percent of Value (%) | Policy Protection per Unit | Premium Rate per $100 | Total Premium | Premium Subsidy | Producer Premium | Actual Index Value | Indemnity |
|---|---|---|---|---|---|---|---|---|
| Jan-Feb | | $0 | 22.77 | $0 | $0 | $0 | 118.4 | $0 |
| Feb-Mar | | $0 | 18.25 | $0 | $0 | $0 | 140.1 | $0 |
| Mar-Apr | | $0 | 13.23 | $0 | $0 | $0 | 95.3 | $0 |
| Apr-May | N/A | $0 | 13.49 | $0 | $0 | $0 | 51.6 | $0 |
| May-Jun | 60 | $78,975 | 12.73 | $10,054 | $5,127 | $4,927 | 54.3 | $31,327 |
| Jun-Jul | N/A | $0 | 16.59 | $0 | $0 | $0 | 52.2 | $0 |
| Jul-Aug | 40 | $52,650 | 16.59 | $8,735 | $4,455 | $4,280 | 78.1 | $6,962 |
| Aug-Sep | N/A | $0 | 15.59 | $0 | $0 | $0 | 107.4 | $0 |
| Sep-Oct | | $0 | 18.63 | $0 | $0 | $0 | 51.6 | $0 |
| Oct-Nov | | $0 | 17.48 | $0 | $0 | $0 | 34.9 | $0 |
| Nov-Dec | | $0 | 24.51 | $0 | $0 | $0 | 45.8 | $0 |
| Per Acre | N/A | N/A | N/A | $7.52 | $3.83 | $3.68 | N/A | $15.32 |
| Policy Total | 2,500 | $131,625 | N/A | $18,788 | $9,582 | $9,206 | N/A | $38,289 |

| | |
|---|---|
| County Base Value | $39.00 |
| Dollar Amount of Protection | $52.65 |
| Total Insured Acres | 2,500 |
| Total Policy Protection | $131,625 |
| Subsidy Level | 51.0% |
| Maximum Percent of Value per Index Interval | 60.0% |

# Participating Acres: U.S. total

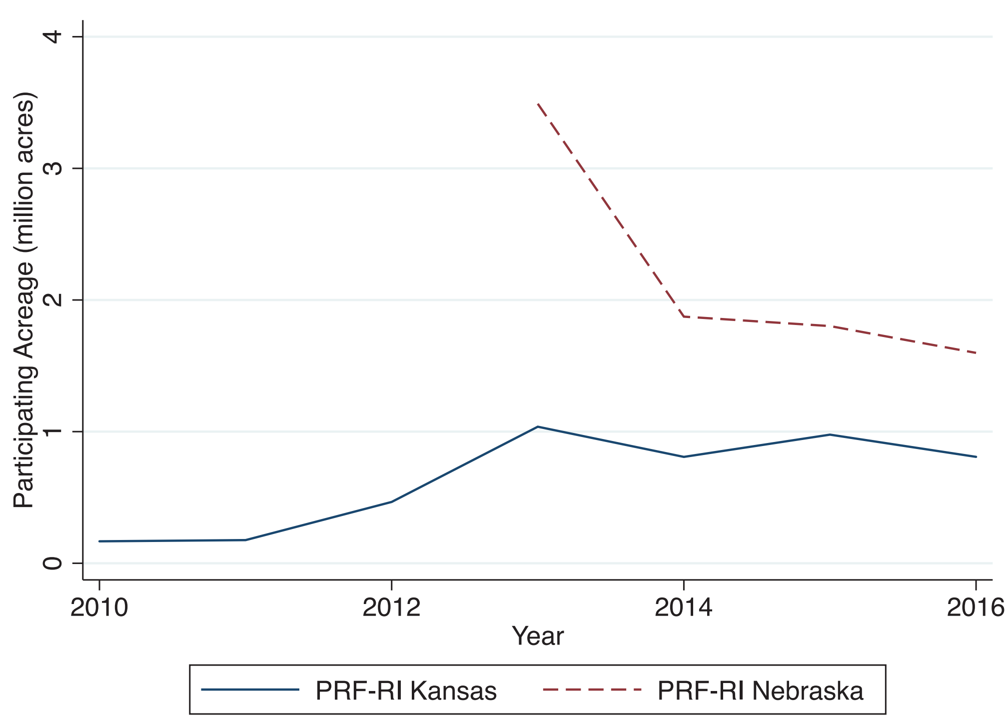







# Participating Acres: Kansas and Nebraska (RI)

Pastureland: 16 million acres (Kansas) and 22 million acres (Nebraska)



## What is Basis Risk?

1. Index insurance participants face a probability that they would not be indemnified even when losses occur (Basis risk).
2. High correlation between individual outcome and indices means **small basis risk**.
3. If the rainfall indices explain forage yields well, the PRF-RI program would have small basis risk.





## Previous Studies on Basis Risk for Index Insurance

1. Basis risk reduces the demand for index insurance (e.g. Clarke 2016; Elabed et al. 2013).
2. Several studies estimate the degree of basis risk for weather derivative or index insurance (e.g. Jensen et al. 2016; Woodard and Garcia 2008). **Estimates on the basis risk for PRF-RI has not documented.**

## Basis Risk for PRF-RI

**Basis risk for PRF-RI has two sources:**

1. Yield variations that are not explained by actual precipitation (Non-precipitation Risk)
2. Measurement error on precipitation, i.e. imperfect correlations between PRF rainfall indices and actual precipitation (Index risk)



Basis Risk for Index Insurance

## How We Measure Basis Risk in PRF-RI

1. Non-precipitation risk: We use errors in predicting yields using actual precipitation More precisely, this risk is measured as one minus the ratio of the prediction error from yield - precipitation regression over the prediction error from using simple mean as the prediction.
2. Index risk: We use the difference between the errors in predicting yields using PRF Rainfall Indices and the errors in predicting yields using actual precipitation.

# Data

1. We use annual forage yields and monthly precipitation data from two university ranches (Barta Brothers Ranch and Gudmundsen Sandhills Laboratory of University of Nebraska-Lincoln).
    1. Barta Brothers Ranch: Data spans from 1999 to 2015. We have plot-level data from 9 plots.

       (N=93, mean of total forage=1,728lb/acre)
    2. Gudmundsen Sandhills Laboratory: Data spans from 2004 to 2015. We only have ranch-level data.

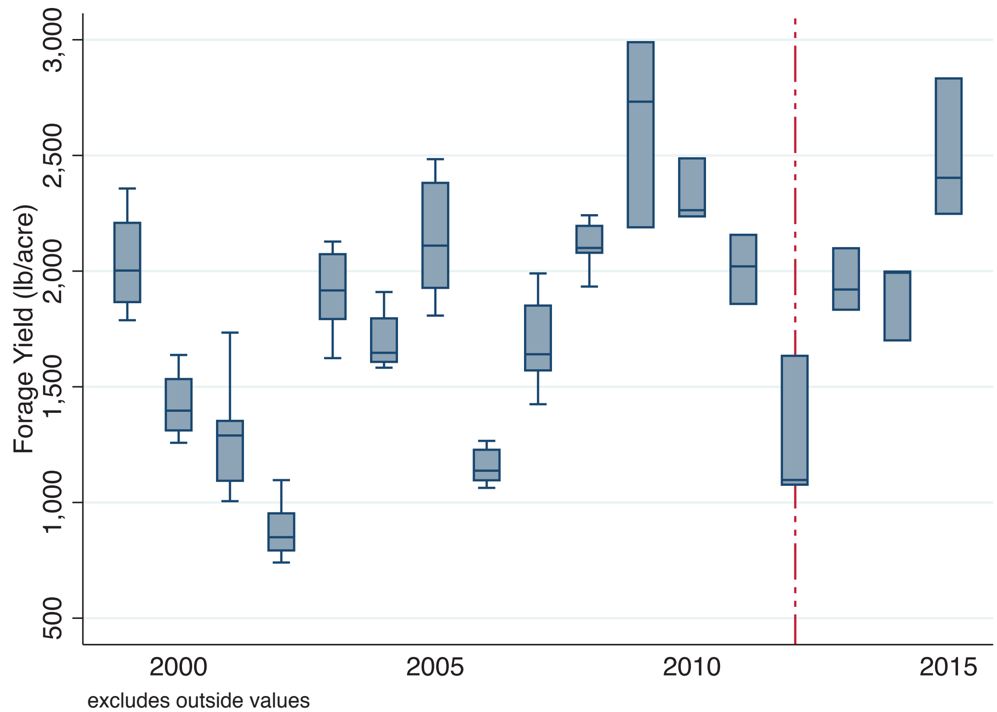
       (N=12, mean of total forage=1,843lb/acre)
2. PRF indices of each 2-month interval for corresponding years and grids are obtained from RMA.





# Yield Trends from the Two Ranches

# BBR Field-level Yield Distributions by Year

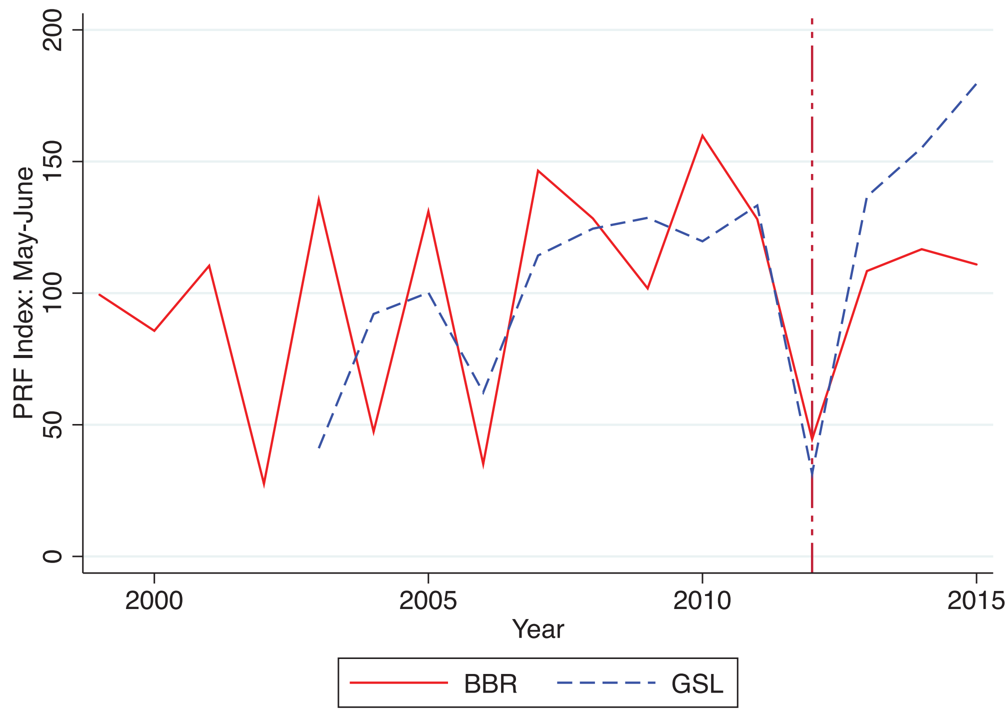







# May Precipitation in the Two Ranches

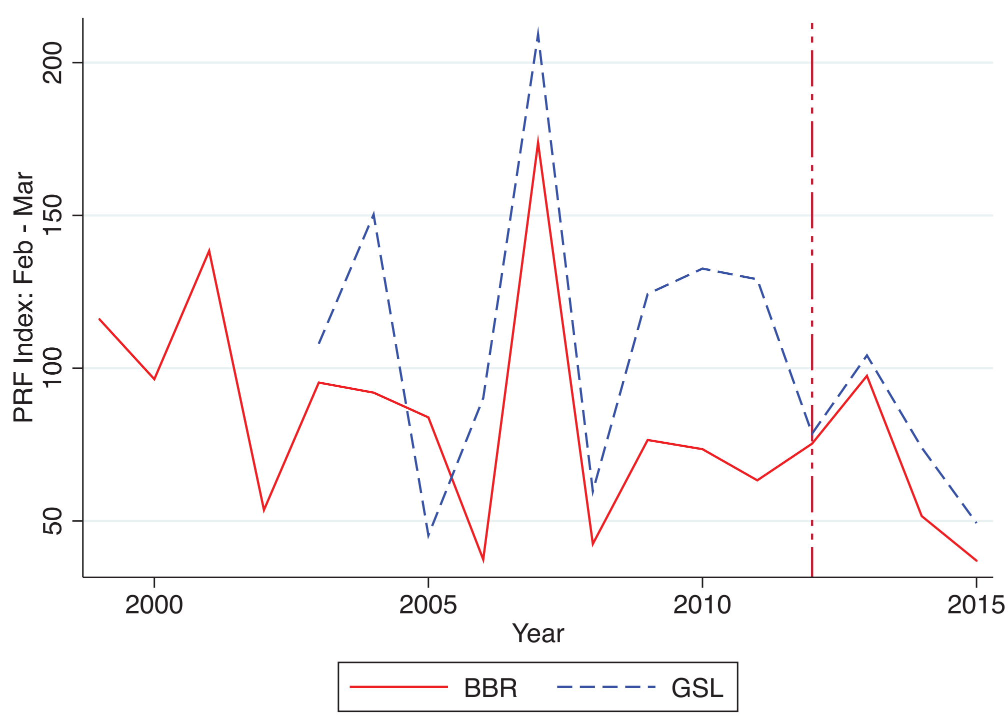
# PRF Index: May - June for the Two Ranches



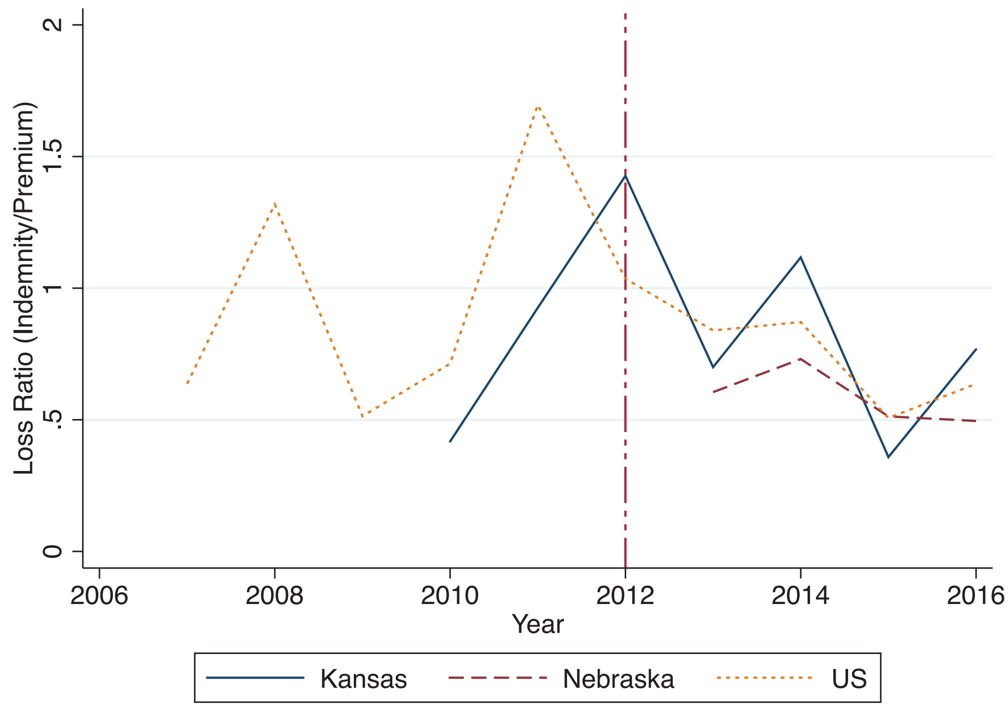





# PRF Index: Feb - Mar for the Two Ranches



# Loss Ratios








# Estimation Equations

1. Yields and Actual Precipitation

$$Yield_{it} = \beta_0 + \sum_{k=1}^{12} \beta_{lag\ k} Precipitation_{kit-1} + \sum_{k=1}^{12} \beta_k Precipitation_{kit} + \gamma_i + \varepsilon_{it}$$

2. Yields and PRF Indices

$$Yield_{it} = \beta_0 + \sum_{k=1}^{11} \beta_k PRF_{kit} + \gamma_i + \varepsilon_{it}$$

$$(+ \sum_{k=1}^{11} \beta_{lag\ k} PRF_{kit-1})$$

## Two Approaches

1. Ordinary Least Squares
2. Regularization Method - Elastic Net Penalty





## Elastic Net Penalty (Zou and Hastie 2005)

Let $Y$ and $X$ be the vectors of dependent and independent variable. The vector of coefficients is $B$ and $p$ is the number of regressors. Then, the elastic net estimator is

$$\hat{B} = arg\ min_{\beta}\{|Y - XB|^2\}$$

$$subject\ to\ (1-\alpha)\sum_{j=1}^{p}|\beta_j| + \alpha\sum_{j=1}^{p}{\beta_j}^2 \leq s$$

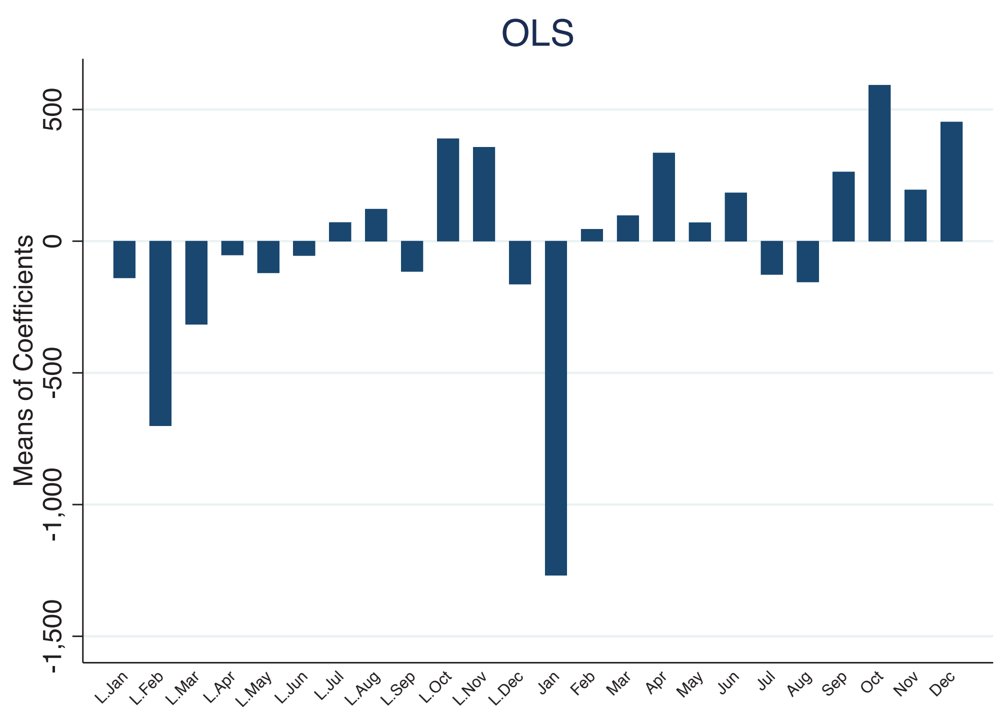
## Cross-validation

1. Step 1: We partition our data into training and test datasets. We exclude one year of observations from our sample and assign them as the "test" dataset. Remaining is the "training" dataset.
2. Step 2: We fit our models to the "training" dataset.
3. Step 3: We compute Root Mean Square Errors (RMSE) using the "test" dataset.
4. Step 4: We repeat Steps 1 through 3 for all 17 years. We report the means of coefficients and the means of RMSE.

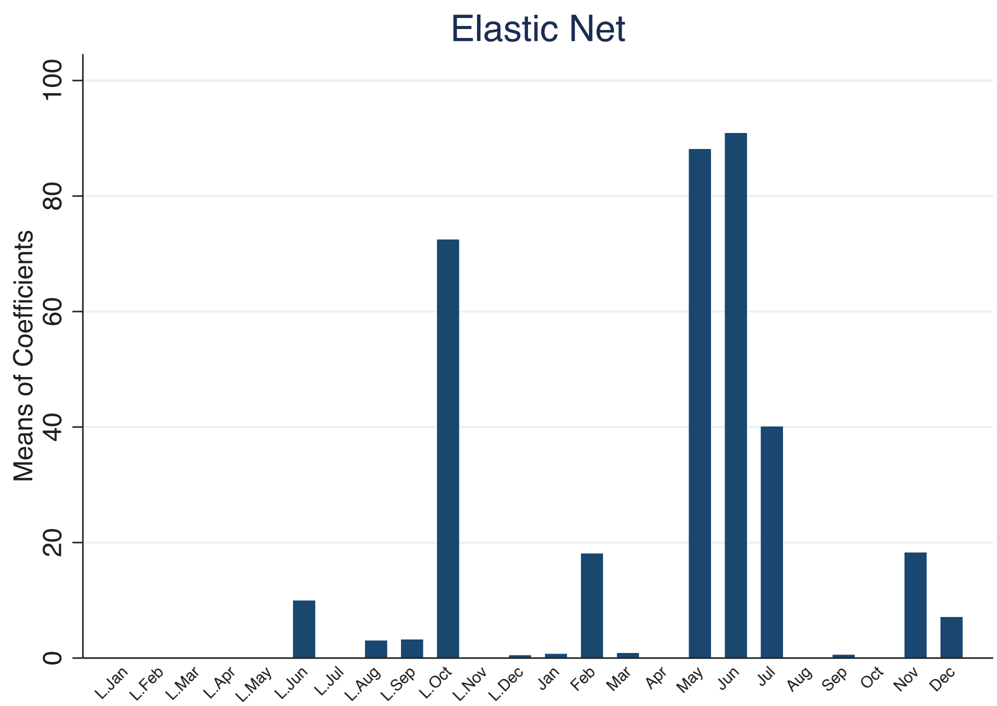




## Yields and Actual Precipitation: OLS



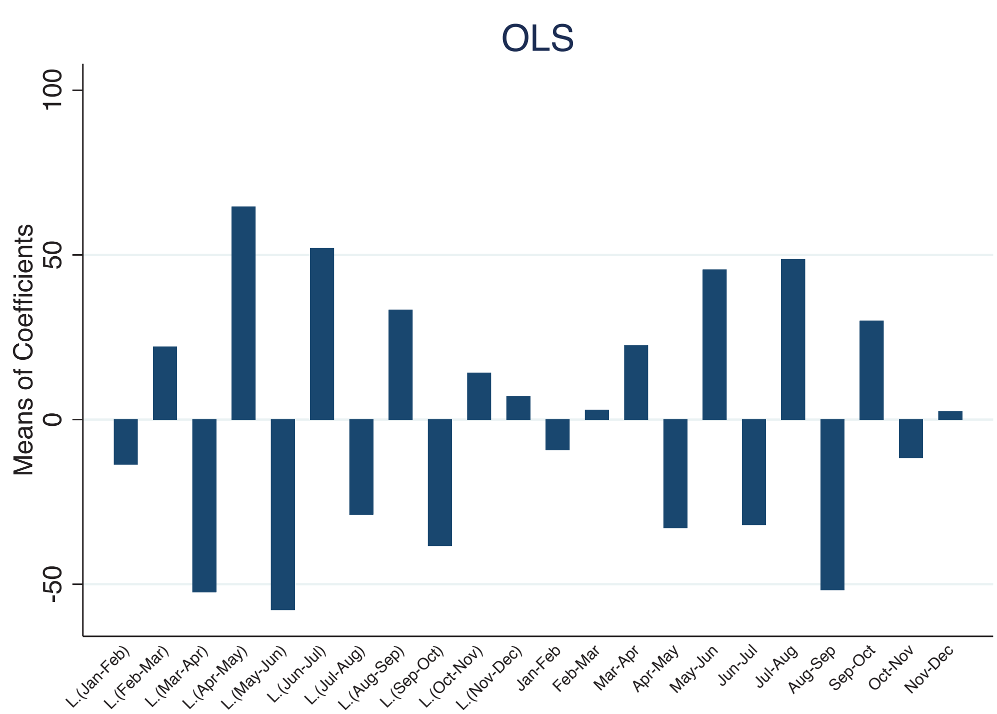
# Yields and Actual Precipitation: Elastic Net



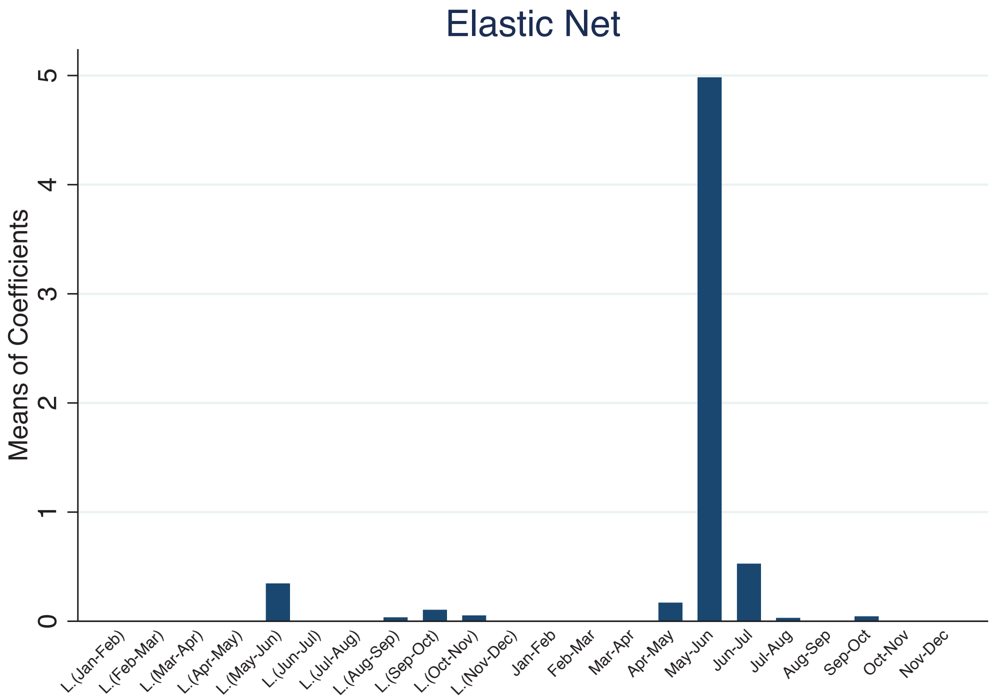





# Yields and PRF Indices with One-year Lags: OLS



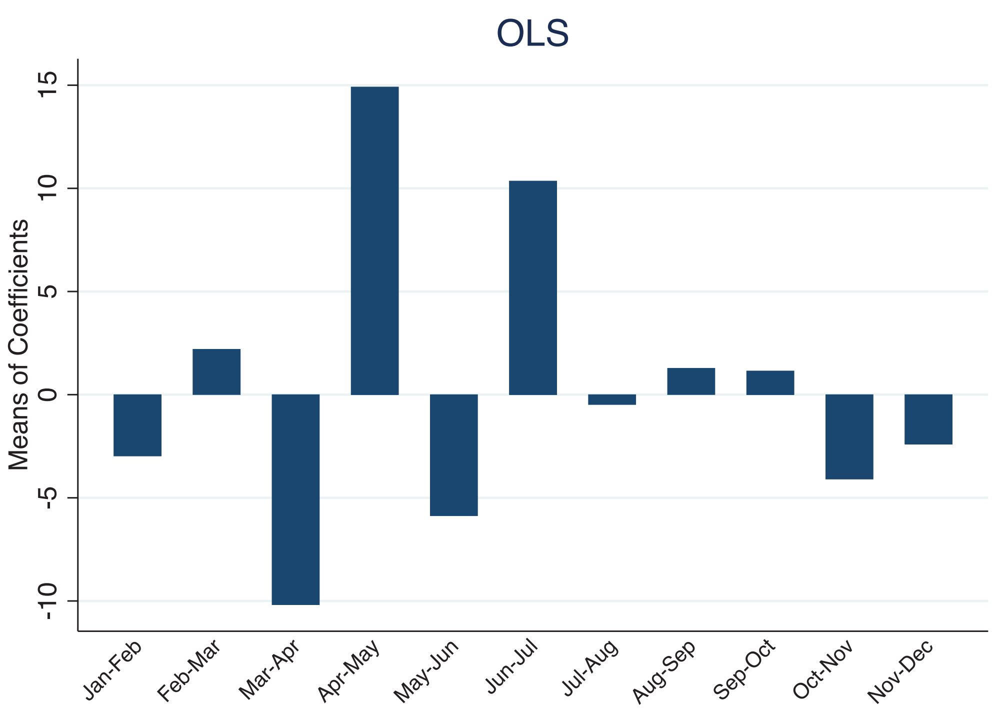
# Yields and PRF Indices with One-year Lags: Elastic Net



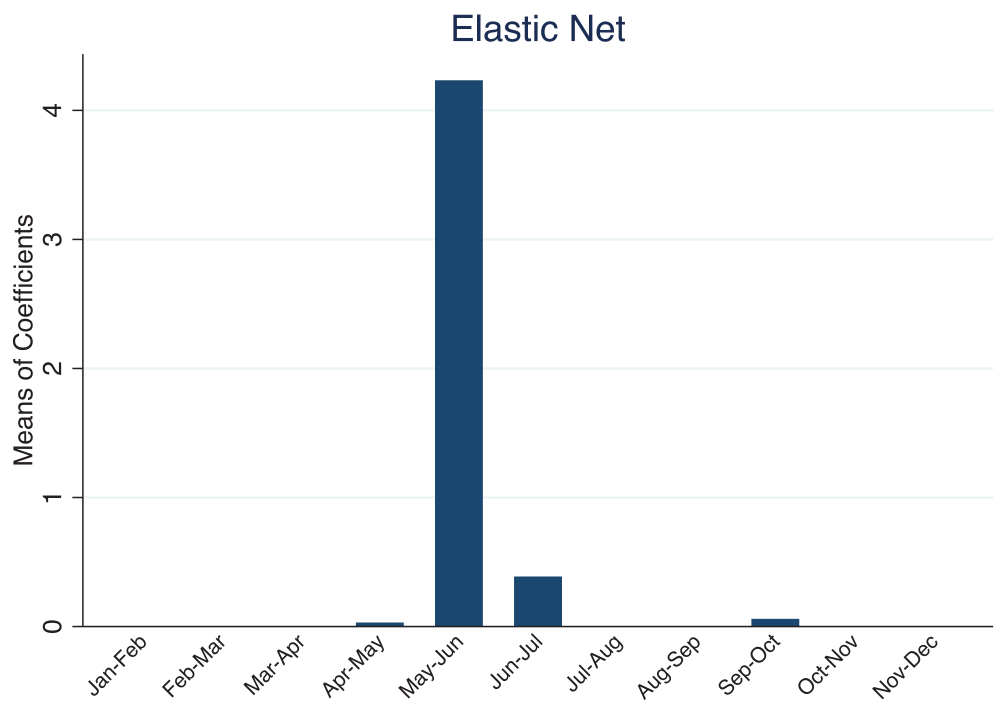





# Yields and PRF Indices: OLS



# Yields and PRF Indices: Elastic Net








# Root Mean Square Errors and the Magnitude of Basis Risk

| Methods | OLS | Ridge | Lasso | Elastic Net | Share over Baseline (%) |
|---|---|---|---|---|---|
| Precipitations | 2637 | 436 | 392 | 391 | 84% |
| PRF | 582 | 443 | 436 | 436 | 93% |
| PRF without Lags | 474 | 434 | 420 | 421 | 90% |

Note: Baseline means RMSE from using field-level temporal yield averages as predictors.

1. Overall PRF basis risk= 90% of yield variation around its mean
2. Non-precipitation risk=84% of yield variation around its mean
3. Index risk= (90-84)/90 %=6.7% of overall PRF basis risk

# Discussion

1. Which months' precipitation matter most?

   **Elastic net selects precipitation in May, June and July.**

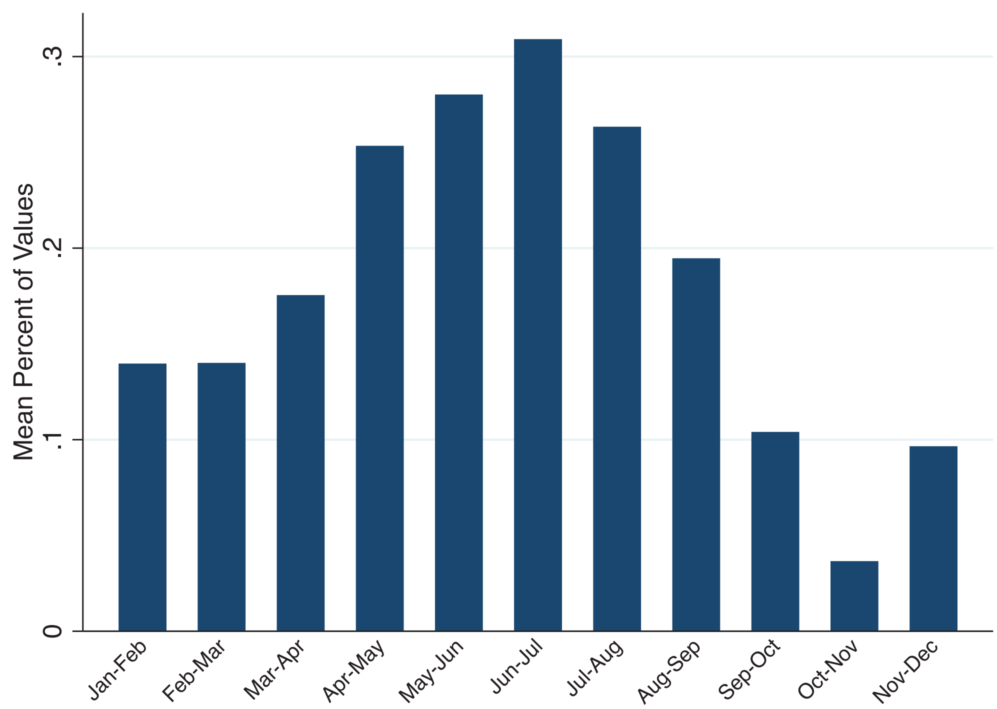
2. Can the basis risk for PRF-RI be reduced?

   **If we use actual precipitation, basis risk would be about 6.7% lower than the PRF-RI.**





# Ranchers' Actual Choices: 2013-2017



## Preliminary Conclusions

1. Precipitation in May - July matters most. The index risk is not very large.
2. Ranchers' choices are different from so-called "optimal" interval choices: This indicates that the actual basis risk is higher.
3. Can we/should we modify the PRF program in a way to reduce the basis risk?: for example, restricting the two-month intervals to the growing season.





## Future Research

1. Examine other hypothesis on low participation rates: learning curve?
2. Explore ranchers' choices on a) the participation and b) the choices on the two-month intervals.
3. Improve the forage yield - precipitation model: consider nonlinear precipitation impacts or separate responses across warm-season and cool-season forage.
4. More data: Another ranch in Hays, Kansas

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