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

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Monte Vandeveer joined the KSU Extension Farm Management team in February 2016 as the Southwest Area extension agricultural economist, based in Garden City. He grew up on a farm in south-central Kansas with wheat and cow-calf operations. He received B.S. and M.S. degrees in agricultural economics from Kansas State University and a Ph.D. in ag economics from Purdue University. Besides working for K-State Research and Extension, he also has experience working with the Economic Research Service, (USDA), the University of Nebraska-Lincoln's Extension Service, and volunteer service in Vietnam. He has a special interest in risk management, particularly crop insurance.

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 14.5% of total pasture yield variation and about 7.7% of the basis risk is due to the difference between actual precipitation and PRF indices.

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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"

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?

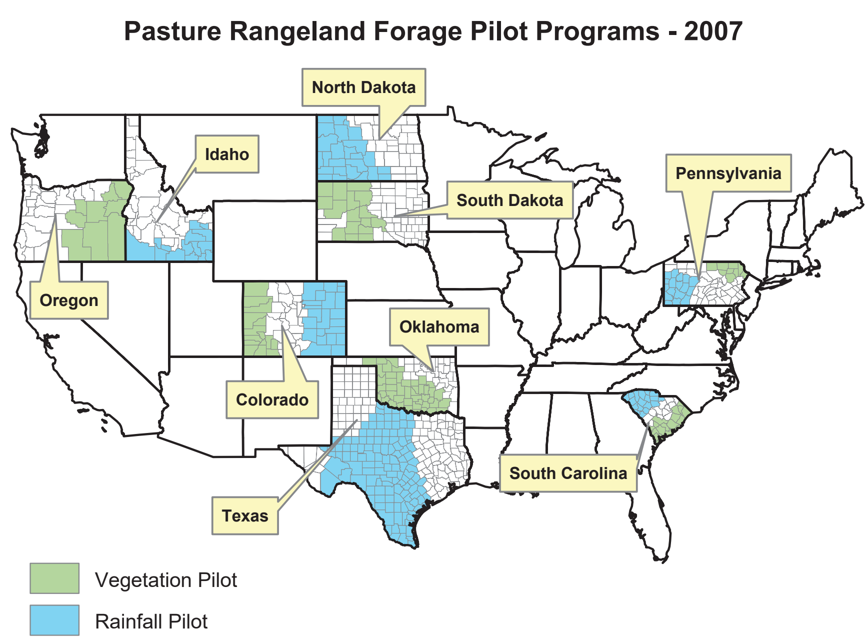
Pastureland and PRF Participation Rates

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.

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.

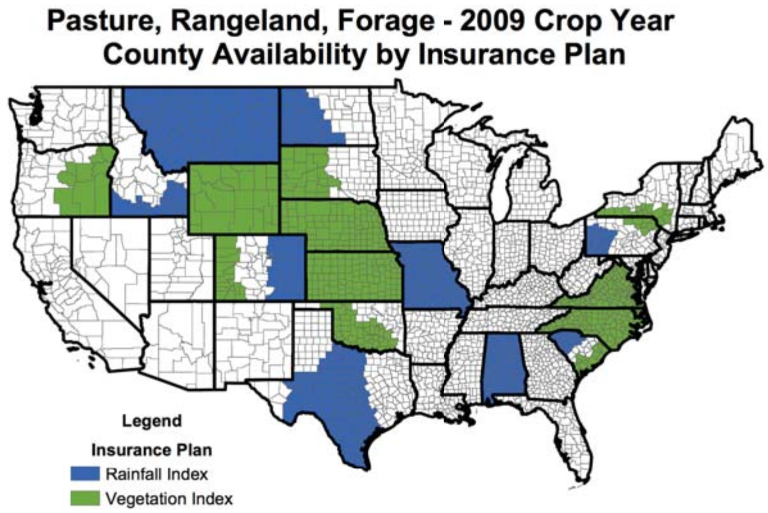
PRF Pilots in 2007



Source: RMA, USDA

PRF Pilots in 2009

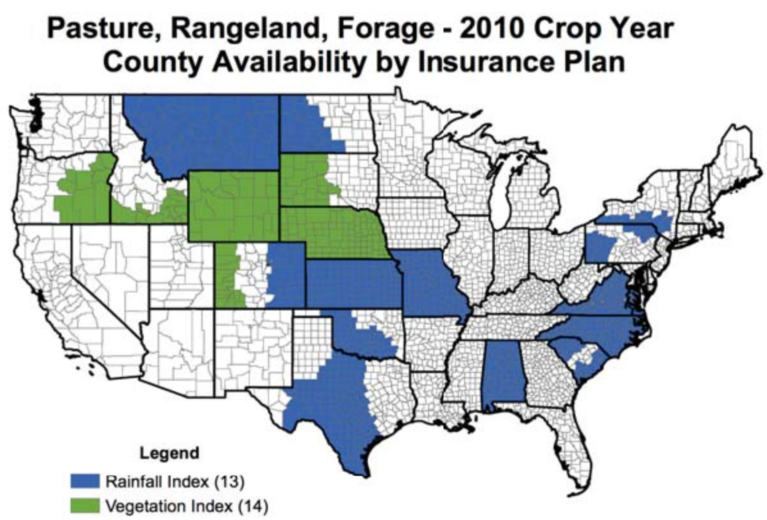
In 2009, PRF was offered to Kansas farms for the first time (VI).



Source: RMA, USDA

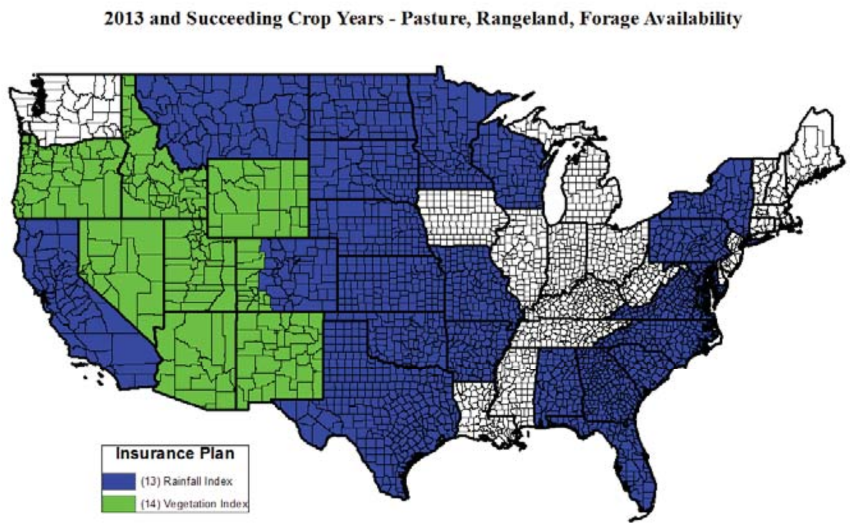
PRF Pilots in 2010

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



Source: RMA, USDA

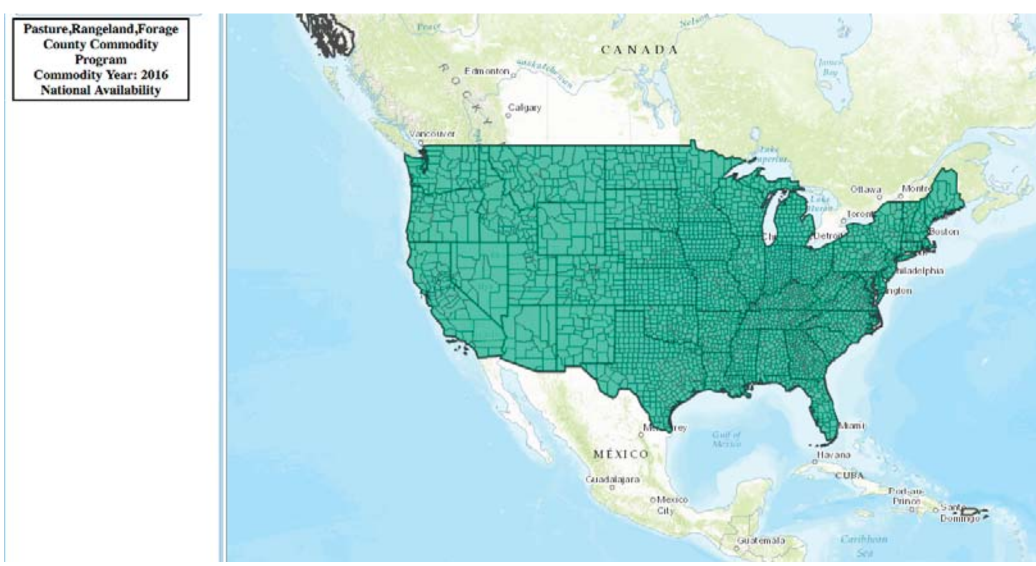
PRF Pilots in 2013



Source: RMA, USDA

Currently,

Only RI program is being offered. All contiguous 48 states are eligible.



Source: RMA, USDA

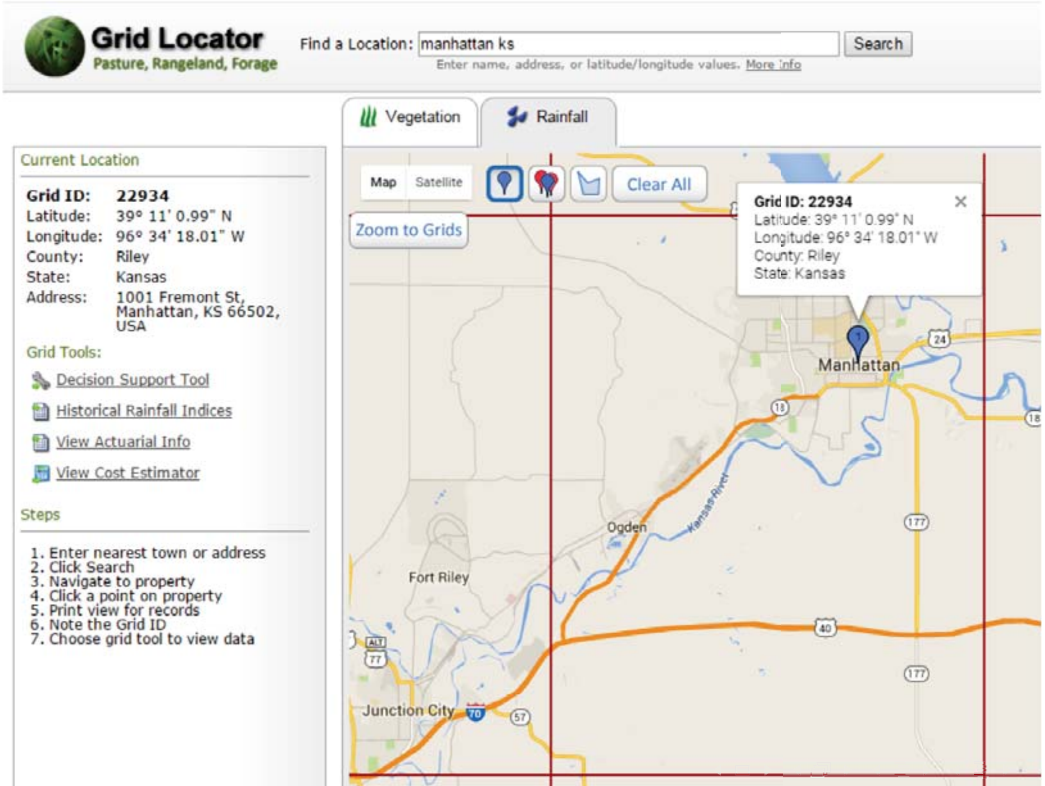
How PRF-RI Works

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%).

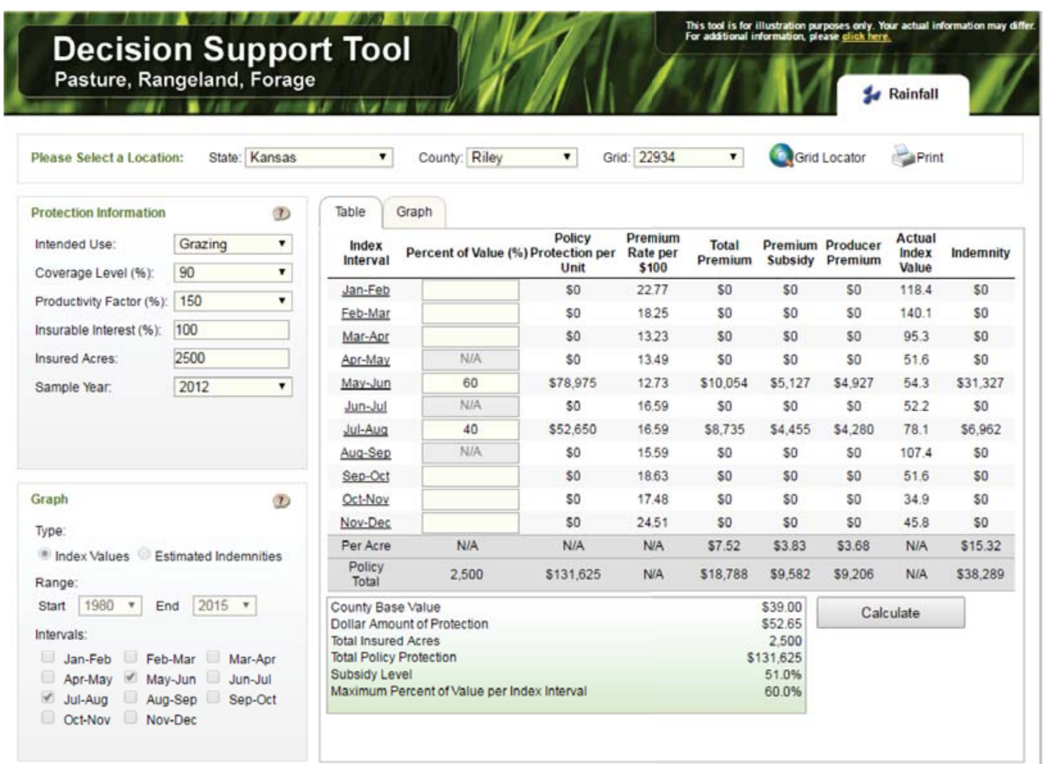
PRF index

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



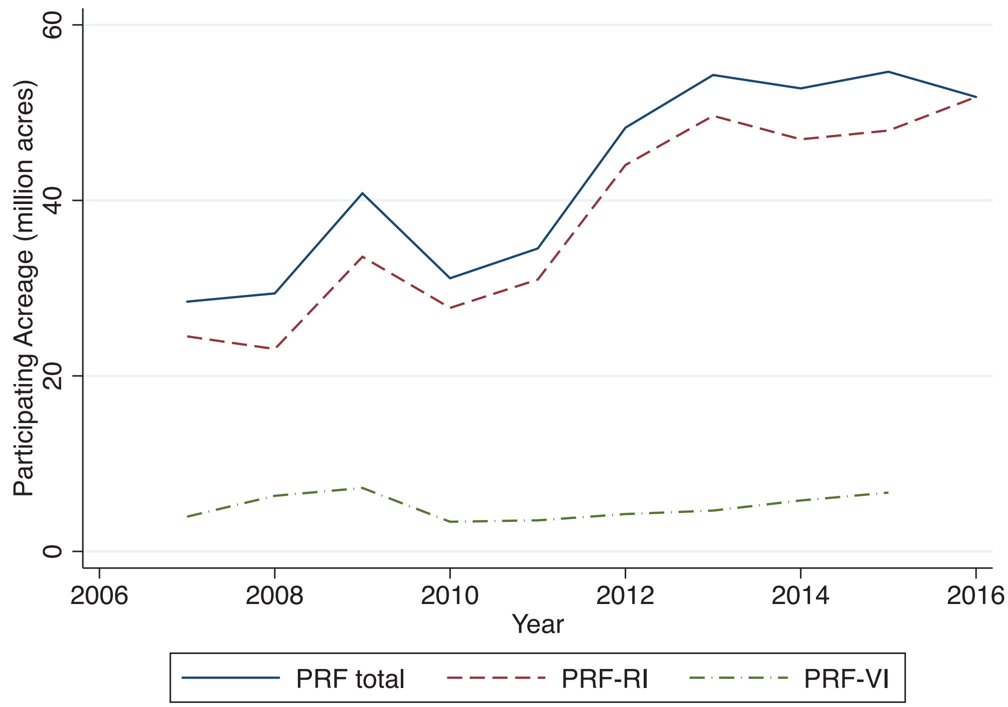
Decision Support Tool



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

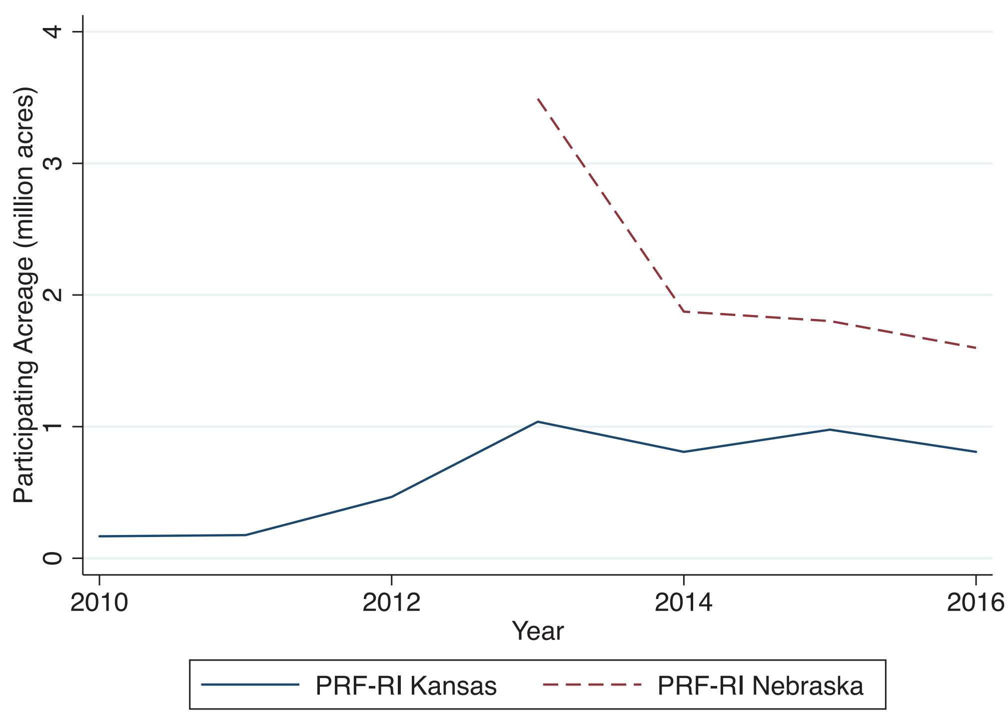
County Base Value	$39.00
Dollar Amount of Protection	$52.65
Total Insured Acres	2,500
Total Policy Protection	$131,625
Subsidy Level	51.0%
Maximum Percent of Value per Index Interval	60.0%

Participating Acres: U.S. total



Participating Acres: Kansas and Nebraska (RI)

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



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)

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)

How We Measure Basis Risk in PRF-RI

1. Non-precipitation risk: We use errors in predicting yields using actual precipitation.
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.

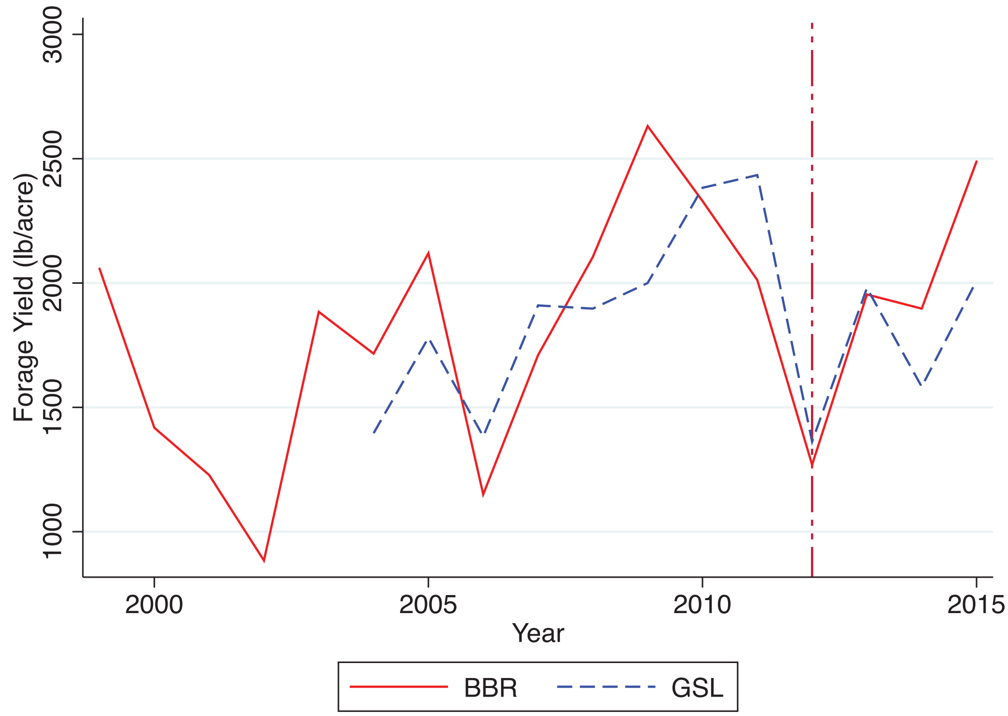
Data

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.

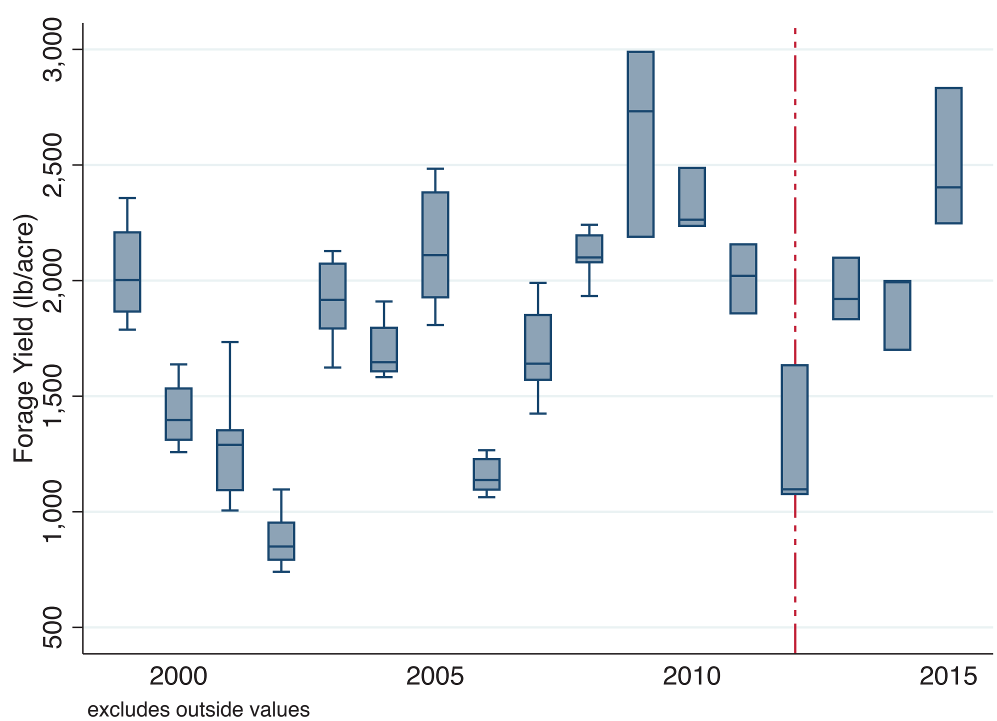
      (N=93, mean of total forage=1,728lb/acre)
   2. Gudmundsen Sandhills Laboratory: Data spans from 2004 to 2015. We only have ranch-level data.

      (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.

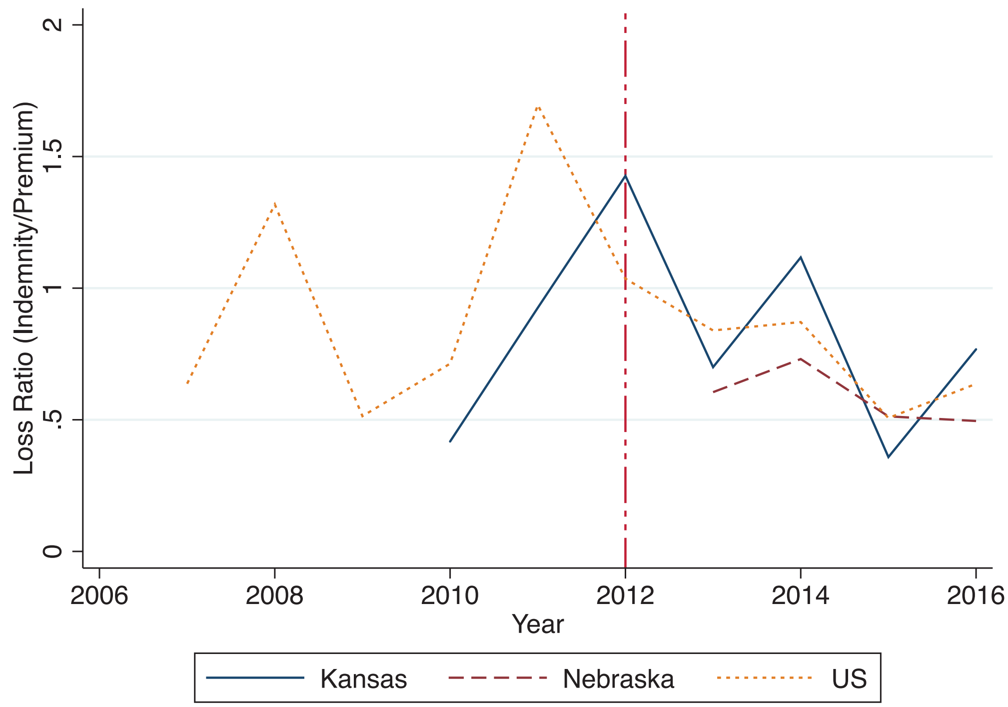
Yield Trends from the Two Ranches



BBR Field-level Yield Trends



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

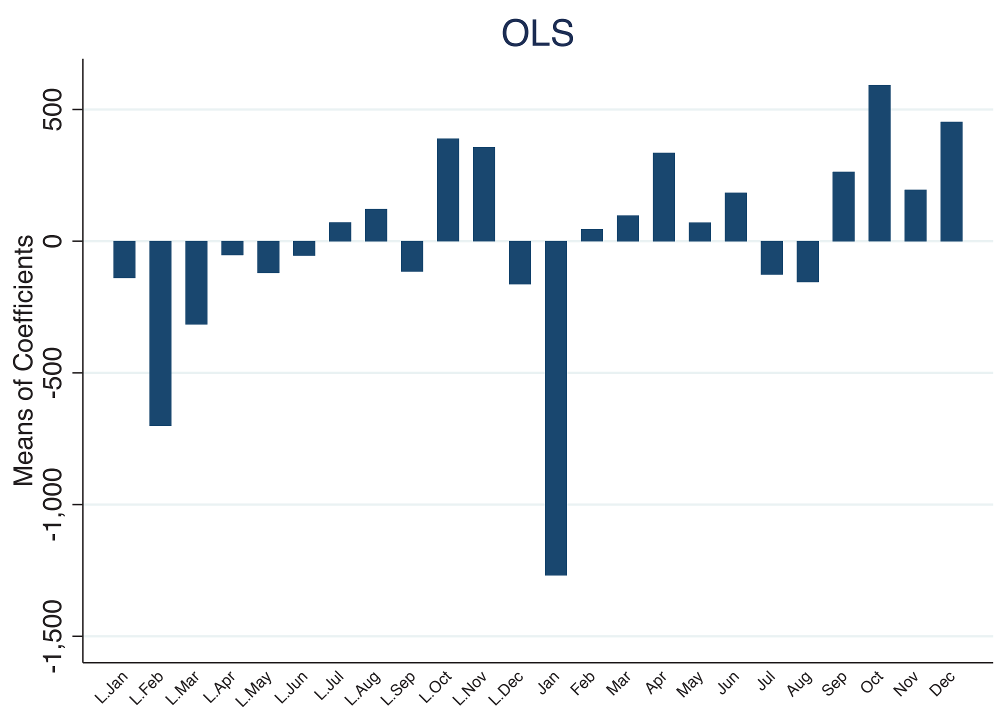
$$\hat{B} = arg\ min_{\beta}\{|Y - XB|^2\}$$

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

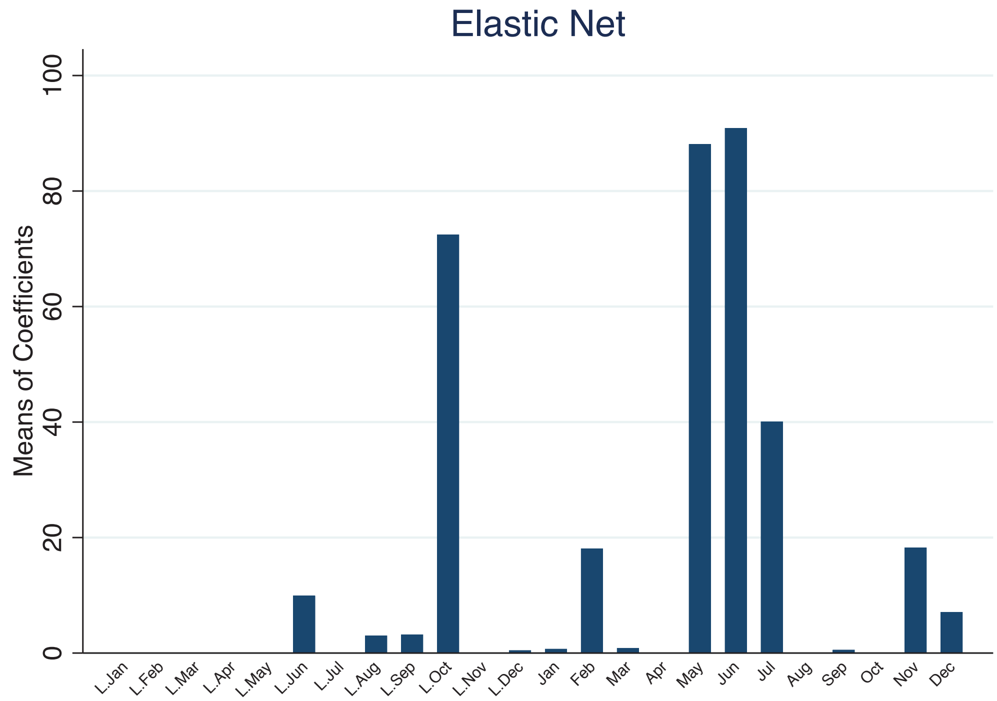
Cross-validation

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.

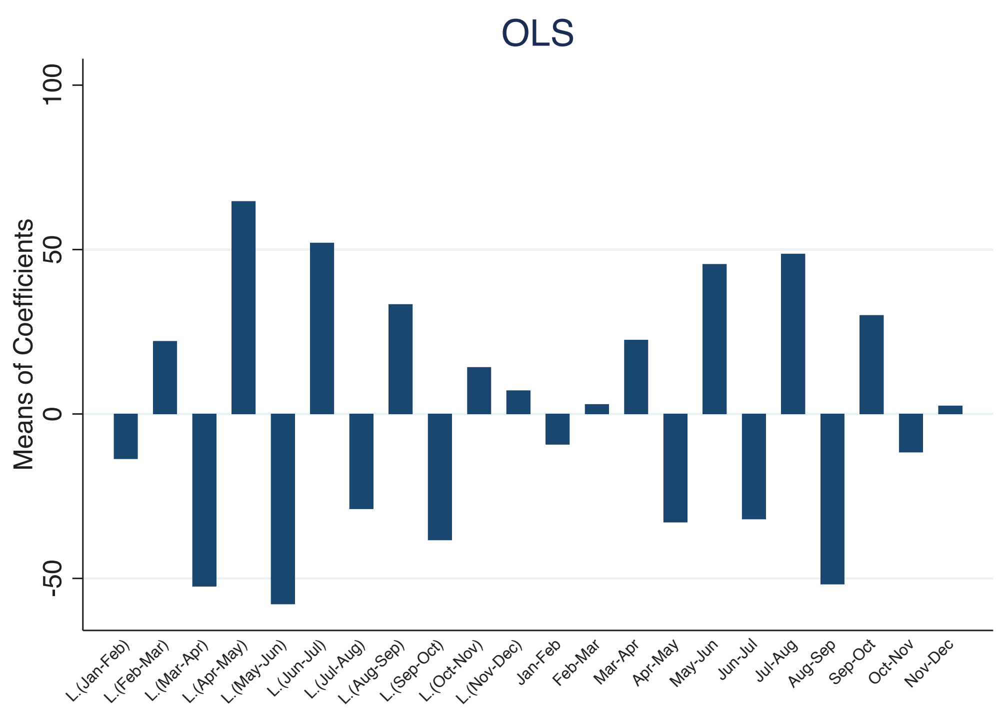
Yields and Actual Precipitation: OLS



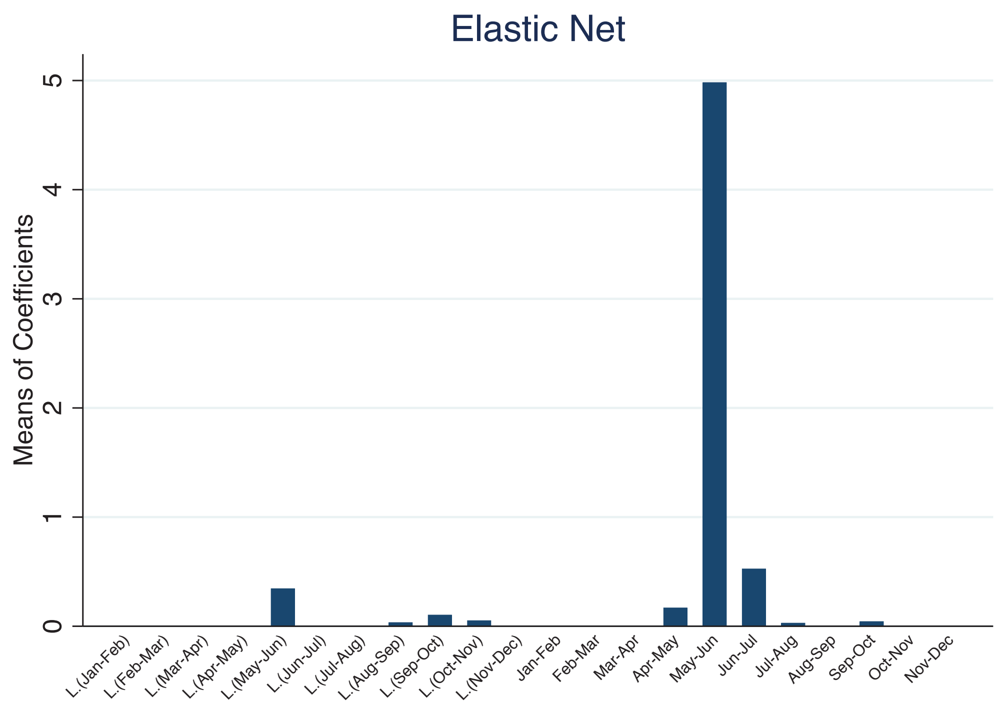
Yields and Actual Precipitation: Elastic Net



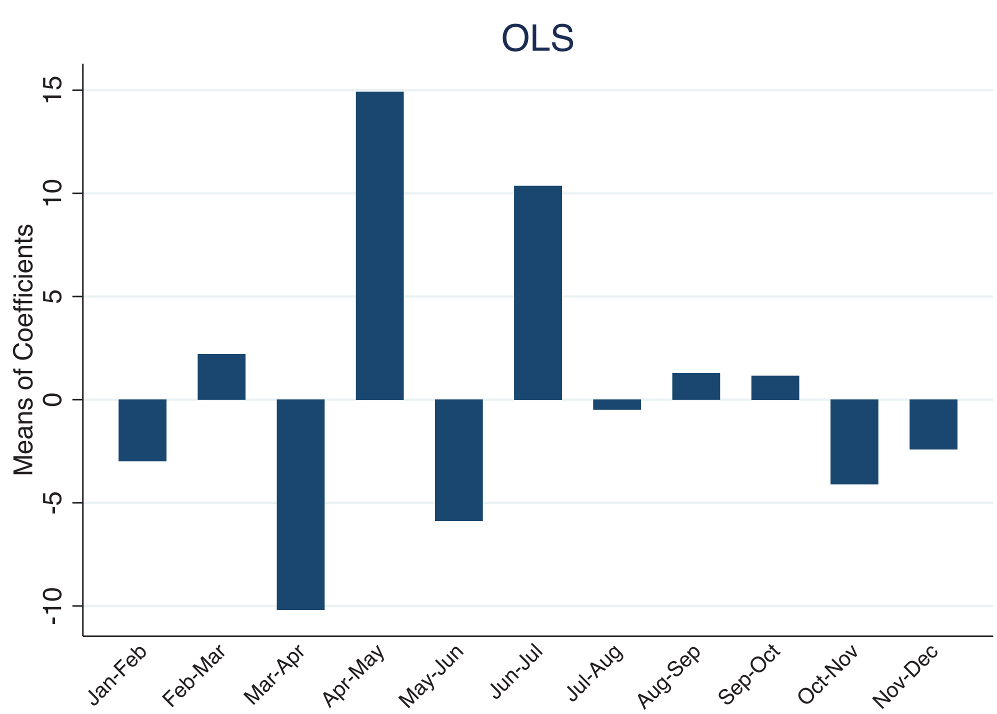
Yields and PRF Indices with One-year Lags: OLS



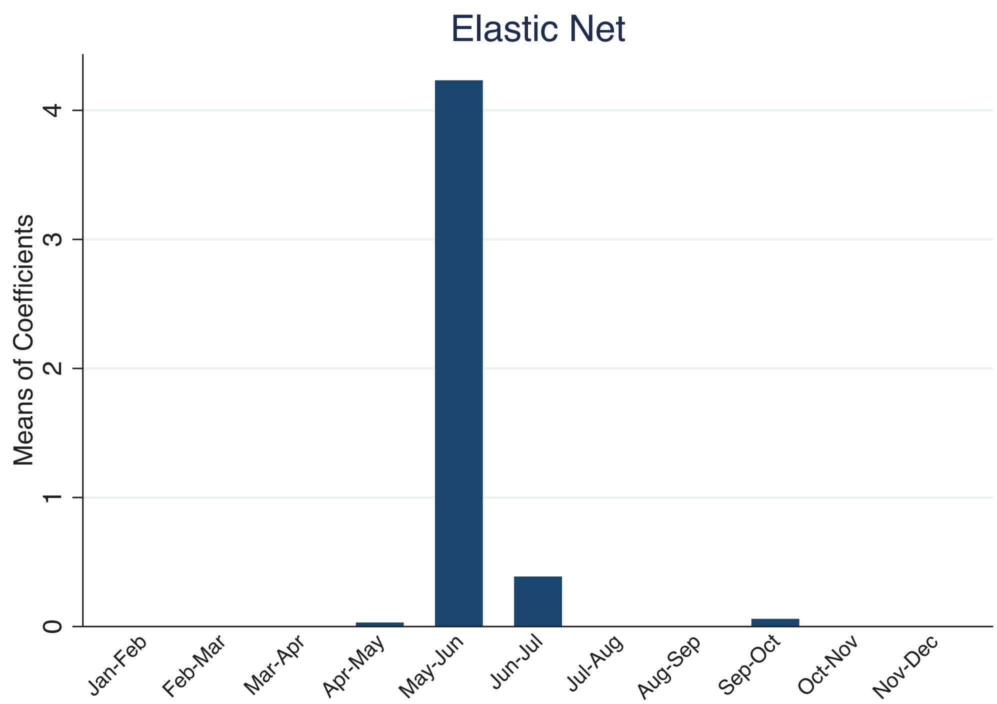
Yields and PRF Indices with One-year Lags: Elastic Net



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.

Discussion

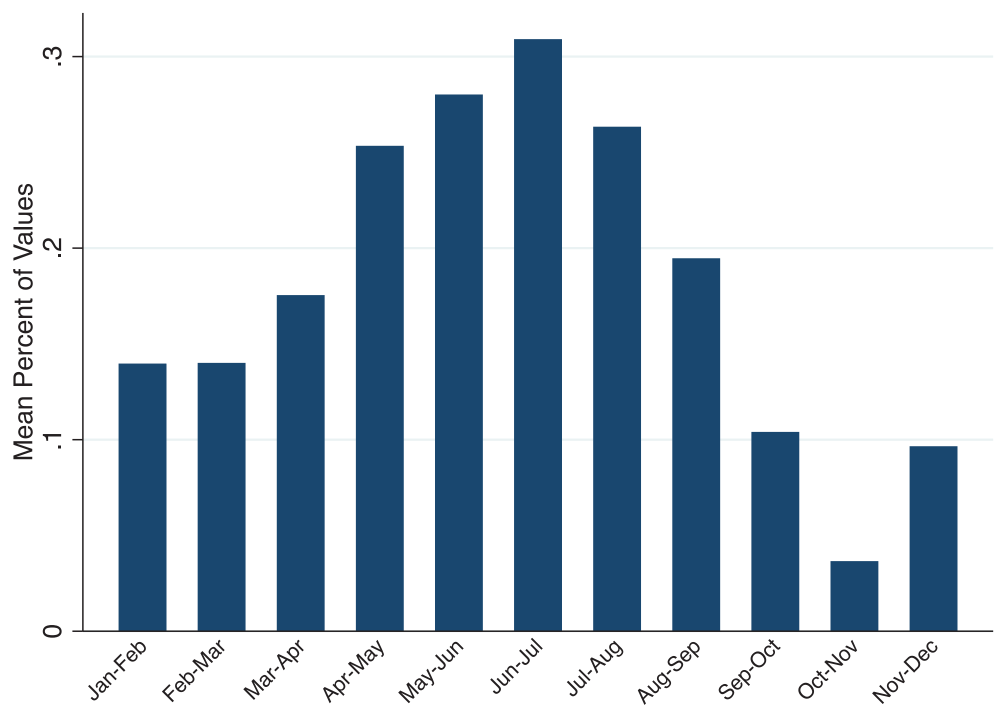
1. Which months' precipitation matter most?

   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 7% lower than the PRF-RI.

Ranchers' Actual Choices: 2013-2017



Preliminary Conclusions

1. Precipitation in May - July matters most. The PRF program has a room to improve.
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?: Possible options are restricting the two-month intervals to the growing season, including the previous year's precipitation, and improving precipitation measures.

Future Researches

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

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