# Demand and Risk Management Analysis of Rainfall Index Insurance

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# DEMAND AND RISK MANAGEMENT ANALYSIS

# OF RAINFALL INDEX INSURANCE

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RAINFALL INDEX INSURANCE

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This thesis has two research chapters regarding the government provided Rainfall Index Insurance for Pasture, Rangeland, and Forage (RI-PRF). In the first chapter, we empirically examined whether charity hazard exists between Rainfall Index Insurance (RI-PRF) and government mandated Livestock Forage Program by estimating the demand for RI-PRF. Evidence was found that lagged LFP payments significantly increase the marginal effects of participating in RI-PRF in three of the five states and in the combined model. These results support the opposite of charity hazard where LFP payments improve the probability of purchasing RI-PRF. In our other models, the results provide evidence in support and against charity hazard in RI-PRF participation. As a result, we cannot definitively accept or reject our hypothesis that charity hazard exists in RI-PRF participation.

In the second chapter, we examined the relation between RI-PRF insurance interval selection and financial outcomes from forage production for two locations in the Sandhills of Nebraska. We find that the risk reducing effectiveness of the monthly insurance interval depends upon expected precipitation. Our results indicate that insurance scenarios containing monthly intervals with high expected precipitation (during the growing season) reduced producer risk. Whereas insurance scenarios containing monthly intervals with low expected precipitation (non-growing season) did not result in

reducing producer risk.  In addition, insurance intervals with low expected precipitation offered the highest net returns to insurance participation at one location, had higher premiums and therefore, higher government cost through additional subsidy dollars per acre.

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Chapter 1: Role of Charity Hazard on the Adoption of Government Provided Index Insurance

## Introduction

The Risk Management Agency (RMA) established Pasture, Rangeland and Forage Insurance (PRF) in 2007 as a pilot program providing livestock producers insurance for their loss of grazing or hay land dependent on either a rainfall index (RI) or vegetation index (VI). In 2016, RI-PRF replaced VI-PRF for all 48 contiguous states. In the 2014 Farm Bill, the government additionally provided mandated livestock disaster assistance programs to help manage feed losses. The Livestock Forage Program (LFP) provides feed assistance payments due to effects of drought or wildfire on grazing lands.

Currently, producers have the option of managing production risk through a fully subsidized government mandated disaster assistance program based on ex-post weather conditions as well as through a partially subsidized ex-ante RI-PRF insurance program. If the producers have incentive to under insure against losses due to adverse weather events, producers may substitute mandated disaster program participation for RI-PRF participation. If the substitution is present because of anticipation of the government assistance, it is considered charity hazard (Coate 1995). In this paper we empirically examine whether charity hazard exists between RI-PRF and LFP programs.

RI-PRF and disaster programs, while similar in that they provide financial assistance to producers stemming from similar events, they provide assistance in fundamentally different ways. First, disaster assistance programs calculate payments based on ex-post disaster conditions taking into account multiple conditions that may contribute to drought such as heat and precipitation. RI-PRF insures against upcoming production uncertainty insuring only a single peril, precipitation. Second, government mandated disaster assistance is 100% subsidized (zero producer paid premium), compared to RI-PRF which is subsidized between 51-59% based upon coverage level.[1] RI-PRF allows producers to choose their contract specificity and with the ability of choice, they are subject to pay higher premiums. Finally, RI-PRF is insuring precipitation based on a rainfall index from a 17-mile by 17-mile grid, while LFP is based on the entire counties drought classification. Disaster payments are affected by county size since the drought index is based on county level. County size and location can cause regional differences in disaster assistance payments and size of payments for producers.

In 2012, the United States experienced its worst drought in more than 50 years causing adverse events. For example, corn and soybean harvests began earlier than ever recorded, affecting livestock production and global food prices. Hay prices were at record levels and the drought depleted water supplies. For perennial grazing/haying systems, drought caused weed species to expand and decreased perennial abundance. During that year, 59% of the U.S. rangeland and pastures were in poor to very poor condition (USDA-NASS 2012). In response to poor perennial conditions and high feed costs, producers were forced to change their management practices. Most cow-calf producers thinned out their herds by selling to feedlots earlier than expected or culling (Kay 2012). These practices were used to help minimize their losses. LFP and RI-PRF were available during the drought, however, they both had their disadvantages for this catastrophic event. Producers had to sign up for RI-PRF in November 2011 for 2012.

[1] To sign up for LFP, the producer must go to their FSA office and sign up for the program. This could be considered a cost, but the producer paid premium is zero.

RI-PRF was also not available in all states.[2] On the other hand, LFP was not offered until 2014 and distributed back payments for 2012 and 2013. However, producers did have knowledge about LFP coming into effect from the 2008 Farm Bill and the proposed 2012 Farm Bill, which discussed mandated disaster assistance for livestock producers.

RI-PRF and VI-PRF together sold 22,130 total policies resulting in $185.73 million of indemnities paid out in 2012 (USDA-RMA 2012). LFP provided $2579.35 million for 287,426 policies for 2012 (USDA-FSA 2014). For 2016, RI-PRF enrolled 28,538 policies providing coverage on more than 52.3 million acres (USDA-RMA 2017b). The insured acreage represents only about 8% of the total 649.5 million acres of pasture and hay land (USDA-NASS 2017). With the small percentage of acres enrolled in RI-PRF, it brings the question if other insurance mechanisms are affecting demand for the insurance product. Since both RI-PRF and LFP are provided by U.S. tax dollars, it is important to evaluate purchasing decisions by producers to insure in the programs.

This article proceeds as follows. We first provide a review of literature regarding demand for insurance based on government assistance. We describe RI-PRF insurance program followed by a description of the LFP disaster assistance program. We then introduce the conceptual model with a description of the data, methods and empirical analysis. Findings are presented and interpreted in the results section, with conclusions in the last section.

[2] Not all states were introduced into the RI-PRF pilot program. Most western states were in the VI-PRF pilot program. Visit the RMA website for maps of availability.

**Literature Review**

Literature contributes to this evaluation of the demand of insurance with the presence of disaster assistance. Raschky et al. (2013) presents an extensive literature review comparing crowd out effects of private insurance due to the presence of ad hoc and disaster assistance. Raschky et al. (2013) examined charity hazard for flood insurance, however, their review provides great depth into the literature discussing government assistance programs.

Literature found that the primary demand for crop insurance is driven by expected indemnities in excess of premiums and varying risk preferences (Goodwin 1993; Barnett and Skees 1995; Just, Calvin, and Quiggin 1999; Babcock 2012). Through conducted phone interviews, van Asseldonk et al. (2002) found Netherlands' producers' anticipated disaster assistance does have an effect on the producer's willingness to pay for crop insurance. This links directly to our analysis of the impact of LFP on demand for RI-PRF insurance. Government relief distorts incentives for producers to pay premiums since the producers do not bear the full cost of their actions (Kaplow 1991). Although a working paper, Deryugina and Kirwan (2016) finds producer's crop insurance expenditures decrease as expected disaster payments increase.

Most literature about disaster assistance has political determinants for the allocation of disaster assistance, however, the allocation of LFP is mandated through the 2014 Farm Bill (Michel-Kerjan and Kousky 2010; Weber, Key, and O 'Donoghue 2016). Mandated disaster assistance provides a clear set of eligibility requirements to receive payments. Producer payments are directly contingent on the weather conditions for their counties. From the clear set of eligibility and payment requirements, it makes political interference less likely than ad hoc disaster assistance.

**VI-PRF Program**

VI-PRF represents an area insurance plan based on Earth Resources Observation Systems (EROS) Normalized Difference Vegetation Index (NDVI) data, using a 4.8-mile square grid. VI-PRF insures eligible acreage for livestock grazing or haying. Producers can select one or more three-month insurance intervals in which NDVI data is important for their forage production (USDA-RMA 2017a). Insurance payments to the producer are calculated based on deviation from the normal NDVI within the grid and index interval selection. When the grid's accumulated index falls below a "trigger grid index", insured producers may be indemnified.

Coverage levels are chosen from 70%-90% in 5% increments varying by county and production type. Productivity factors vary from 60% to 150% of county base value in 1% increments. The 70% and 75% coverage levels are subsidized at 59% of the premium. For coverage levels of 80% and 85%, 55% of the premium is subsidized. Lastly, for 90% coverage level, 51% of the premium is subsidized.

**RI-PRF Program**

RI-PRF represents a single peril index insurance product focusing on the production of perennial forages on rangeland, pastureland, and cropland. The objective of RI-PRF is to provide perennial forage producers revenue due to losses in precipitation (USDA-RMA 2017a). To be eligible for RI-PRF, the producer is required to have a share on insurable acreage that was in production before July 1 prior to the coverage year. RI-PRF offers a variety of contracts based on varying coverage levels and productivity factors. Coverage levels are chosen from 70%-90% in 5% increments varying by county and production type. Productivity factors vary from 60% to 150% of county base value in 1% increments.

RI-PRF insures by grids created by the National Oceanic Atmospheric Administration Climate Prediction Center and do not follow geopolitical boundaries. The gridded precipitation data represents an interpolated value based on the entire grid and cannot be traced to a single point or reporting station. RI-PRF requires the producer to insure monthly precipitation using two-month intervals. RI-PRF is available for the entire calendar year and not only during the grazing or haying season. Losses are calculated based on whether the current year's precipitation in a grid has deviated from the historical normal precipitation in the same grid, for the same interval. The 70% and 75% coverage levels are subsidized at 59% of the premium. For coverage levels of 80% and 85%, 55% of the premium is subsidized. Lastly, for 90% coverage level, 51% of the premium is subsidized.

## Livestock Forage Program

LFP is a disaster assistance program to compensate livestock producers who have suffered grazing losses for covered livestock on land that is native or improved pastureland with permanent vegetative cover or is planted specifically for grazing (USDA-FSA 2017). The grazing losses must be due to a qualifying drought condition during the normal grazing period for the county. An eligible livestock producer would be a producer who owns or leases grazing land or pastureland physically located in a county where the U.S. Drought Monitor declared the county to be within D2-D4 drought intensities (USDA-FSA 2017).

D2 intensity is defined as a severe drought where the crop or pasture losses are likely, water shortages common, and water restrictions imposed (USDM 2017). If any area of the county is in D2 for at least eight consecutive weeks during the normal grazing period, the county is eligible to receive assistance in an amount equal to one monthly payment (USDA-FSA 2017).

D3 intensity is defined as an extreme drought where crop and pasture losses would be major, widespread water shortages and restrictions (USDM 2017). If any area of the county is in D3 at any time during the normal grazing period, the county is eligible to receive assistance in an amount equal to three monthly payments. If any area in the county has a D3 drought for at least four weeks during the normal grazing period, the county is eligible to receive assistance in amount equal to four monthly payments (USDA-FSA 2017).

D4 intensity is defined as an exceptional drought to which there are exceptional and widespread crop/pasture losses, shortage of water in reservoirs, steams and wells creating water emergencies (USDM 2017). If any area of the county is in a D4 during the normal grazing period, the county is eligible to receive assistance in amount equal to four monthly payments. If there is D4 in a county for four weeks during the normal grazing period, the county is eligible to receive assistance in amount equal to five monthly payments (USDA-FSA 2017).

FSA created the LFP payment rate for drought which is equal to 60 percent of the lesser of either the monthly feed cost for all covered livestock owned or leased by an eligible livestock producer or calculated by using the normal carrying capacity of the eligible grazing land of the eligible livestock producer (USDA-FSA 2017). Total LFP payments to an eligible livestock producer in a calendar year for grazing losses does not exceed five monthly payments for the same livestock. If an eligible livestock producer sold or otherwise disposed of livestock because of drought conditions in one or both of the two previous production years immediately preceding the current production year, the payment rate will equal 80 percent of the monthly payment rate. No one person or legal entity may receive more than $125,000 total in payments in all disaster assistance programs combined (USDA-FSA 2017).[3] To sign up for the program, the eligible livestock producer must go to their local FSA office within 30 days of qualifying drought conditions to fill out paperwork.

## Conceptual Model

Following Raschky and Weck-Hannenman (2007), we assume counties are utility maximizers that obtain an amount of insurance coverage $V(\alpha)$ to insure against a potential loss $L(\alpha)$, where $\alpha$ is the insurable acres. Figure 1, shows two types of states of the world. State 1 ($S_1$) is assumed to be a year without any adverse weather events. State 2 ($S_2$) is subjected to an adverse weather event. Counties in $S_2$ are trying to determine the level of insurance coverage to have the same wealth as in $S_1$. It is assumed that

[3] These disaster assistant programs include Livestock Indemnity Program (LIP) and Emergency Assistance for Livestock, Farm Raised Fish and Honeybees (ELAP).

insurance is set as an actuarially fair premium, $P(\alpha)$. Each county is allocated an initial wealth of $W_0$. Government provided disaster assistance can be paid through different amounts depending on the severity of the weather event where $\theta_1 < \theta_2 < \theta_3$. As theory suggests, the largest government provided disaster payment ($G_3$) will keep counties from enrolling in the insurance because counties are able to move to a higher indifference curve ($I_2$). For the small level of government provided disaster assistance ($G_1$), counties will cover at point $C$ (the highest coverage level) to insure their potential loss. For the medium level of government provided disaster assistance ($G_2$), counties are indifferent between point $C$ and $D$ since both are on the same indifference curve ($I_1$). Counties chose their coverage depending on their expected government provided assistance. This idea that counties base their decisions on whether or not to buy insurance or underinsure based on anticipated government assistance motivated the empirical analysis shown in the following section.

**Data and Methods**

The current research uses a detailed RI-PRF and VI-PRF data set provided by the Risk Management Agency. RMA provides historical information for their programs on their website (USDA-RMA 2017c). Data were collected for all counties in the top five cow-calf producing states. The top five cow-calf states in 2017 were Texas, Nebraska, California, Oklahoma, and Kansas (LMIC 2017). For each county, detailed policy information was provided for the years 2012-2016, including number of acres enrolled, premiums paid, liability per acre, indemnity, coverage level, subsidy.[4] For RI-PRF acres enrolled, the return from insurance per acre was calculated as enrolled indemnities minus premiums paid.

LFP data were obtained from the Farm Service Agency through a freedom of information act acquisition. Data provided historical LFP payments by year by county within those five states along with the number of requested payments. We assume that it costs the producer zero dollars to sign up for LFP payments. Therefore, we calculate LFP payment per acre by taking the payment over the total county pastureland acres (USDA-NASS 2017a). County level data was analyzed because farm level data for insurance policies and disaster assistance payments cannot be used for confidentiality purposes. Median household income for each county was found on County Health Rankings (2017).

Following Browne and Hoyt (2000), the current research uses an empirical analysis to determine the interrelationships of ex-ante insurance (RI-PRF) with ex-post insurance (LFP) to determine impacts on producers' risk management decisions. RI-PRF and LFP both cover feed losses for livestock, therefore will be used for analysis.

$$(1) \qquad Y_{ct} = \alpha + \gamma_c + \delta_t + \sum_{k=1}^{4} \beta_k \, LFP_{ct-1} + \sum_{i=1}^{4} \beta_{i+4} \, RIA_{ct-1} + \beta_9 \log(PREM_{ct}) + \beta_{10} \log(W_{ct}) + \epsilon_{ct}$$

Where $Y_{ct}$ is the dependent variable in county $c$ for year $t$; $\alpha$ is the constant; $\gamma_c$ is the year indicator; $\delta_t$ is the county fixed affect; $LFP_{ct-1}$ is Livestock Forage Disaster Payment per acre from the previous year; $RIA_{ct-1}$ is the return from PRF

[4] Nebraska was the only state enrolled in VI-PRF during our analysis and only for Year 2012.

insurance per acre from the previous year; $\log(PREM_{ct})$ is the log of premium paid per acre; $\log(W_{ct})$ is the log of wealth; and $\epsilon_{ct}$ is the error term. Two dependent variables were used to measure the demand for RI-PRF insurance. The first variable (model 1), $RIPRF_{ct}$, is the percent of acres enrolled in RI-PRF. The second variable (model 2), $RILIA_{ct}$, is the amount of liability.

We build upon Raschky and Weck-Hanneman (2007) by breaking out the impact of different sizes of disaster assistance (LFP) payments to evaluate their marginal effects on RI-PRF. $LFP_{ct-1}$ payments were calculated per acre by taking the county LFP payment divided by the amount of pastureland acres in the county. Since the whole county is able to receive payments if any part of the county is in the drought zone, we are able to assume that every acre in the county received some of the payment. Pastureland acres were assumed to be constant from 2012-2016. $LFP_{ct-1}$ is used for the hypothesis that the larger the payment from a fully subsidized insurance program (disaster assistance) negatively affect the enrollment into a premium required insurance program based on rainfall indices and intervals. Disaster payments, $\sum_{k=1}^{4} \beta_k \, LFP_{ct-1}$were divided into four categorical bins; Zero LFP payment, Small LFP payment, Medium LFP payment, and Large LFP payment. Zero LFP payment was created for all counties in which no LFP payments were made in a given year. For counties within a given year that received an LFP payment, bins were created using quartiles where the top 25% of the payments were classified as large LFP payments, bottom 25% as small LFP payments, and the middle 50% were grouped as medium LFP payments. Table 1 reports LFP payments per acre summary statistics for the combined and individual state models along with the mean of each bin. We created different LFP bins for each individual state in order to show regional effects.

To determine if the past returns from insurance affected the enrollment in the current year's insurance program, we lagged returns from insurance ($RIA_{ct-1}$). The RIA is per acre where the county return was divided by the total acres enrolled in the program. RIA was separated into four different categories in order to determine if the magnitude or sign of the lagged return affected current percent of acres enrolled and/or the liability per acre in RI-PRF. The bins are categorized as negative returns, between returns, positive returns, and no acres enrolled in the program. Negative returns mean the producer paid more into premiums than received in indemnities. Positive returns mean the producer received more in indemnities than paid in premiums. The no acres enrolled category was created for any county in which no acres were enrolled in a PRF program in a given year. For counties in which acres were enrolled in PRF in a given year were distributed into bins based on the return using quantiles. The lowest 25% of returns were classified into the negative return bin since the mean for that bin is negative for the combined and each individual state. In the second bin, we grouped the middle 50% into a bin as the between returns. Lastly, our positive returns are the largest 25% of the returns. With the bins, we are able to capture the effect of large positive and large negative returns on demand. Summary statistics for the RI-PRF returns for the combined model as well as all the states is reported in Table 2.

Premiums paid per acre per county was logged for our regression ($\log(PREM_{ct})$). The RMA data contained premiums paid, which were then divided by acres enrolled in the insurance to create the premiums paid per acre by county. No premium prices were given for counties who did not participate in the program in a given year, therefore, premiums for those counties were set as the average of the state premium paid in the program in a given year. Even though counties did not participate in RI-PRF, they are still faced with premium prices.

RI-PRF premiums and deciding whether to enroll acres into RI-PRF or how much liability to purchase are jointly determined and can cause endogeneity. Using the Durbin-Wu-Hausman test we found endogeneity in some of the models. Out of 18 tests (6 models (5 states and one combined) with 3 dependent variables) 11 were statistically significant. We instrumented RI-PRF premium using lagged RI-PRF premium, lagged wealth, and year indicators.

RMA recently released RI-PRF, therefore many counties did not have any enrollment, causing a large number of observations at zero. A selection model was first estimated to focus on the probability of purchasing RI-PRF. For the selection model, the dependent variable of whether or not a county enrolled in RI-PRF in a given year was represented with a 1 if a positive number of acres in a county in a given year were enrolled in RI-PRF. Marginal effects are then calculated for the selection model in order to interpret the coefficients. From the selection model, data was removed where there was zero acres enrolled in insurance for our percentage of RI-PRF acres enrolled model and amount of liability enrolled model.

Equation (1) was estimated for each state along with one combined state model. For the combined state a state fixed effect was used instead of the county fixed effect because the counties in zero were perfectly predicting the selection model. Both the selection model and regression models have the same explanatory variables from equation (1).

## Results

Table 3 reports the marginal effects from the selection model for the combined model (all states) and the individual state models.[5] The constant in the combined model represents California in 2013, zero LFP payments and not enrolled in RI-PRF the previous year.[6] For the state models the constant represents zero LFP payments and not enrolled in RI-PRF the previous year. Log of premium was significant and positive in three states- Nebraska, Oklahoma, and Texas. This result is counter intuitive because one would expect premium to be negatively related to participation. A likely reason for this result is due to the fact that premiums vary substantially upon the insured months and the productivity factor. As a result, it may be possible that participants are selecting to insure in the months with the higher premiums, possibly at higher productivity factors. The log of wealth was found to be significant with differing signs in the selection model in two states: California (negative) and Oklahoma (positive). We found negative significant results for the year indicator in all models but two states – Kansas and Texas. Year indicator 2014 was significant and negative for the combined, Nebraska, and Oklahoma. Since the drought occurred mostly in 2012, year indicator 2014 suggests that counties are less likely to enroll in RI-PRF compared to 2013. For 2013, counties were experiencing a drought during signup period, so they would be more likely to purchase insurance. Year

[5] Parameter estimates can be made available by contacting the authors.
[6] State fixed effects were not included in Table 3 but available upon request.

indicator 2016 was significant and negative for combined, California, and Oklahoma. A result suggesting as counties move further away from the drought year, they are less likely to purchase RI-PRF.

For lagged LFP payments, we found at least one significant and negative response in only one state, California for small LFP payment. This result suggests that charity hazard exists in livestock insurance. However, we did not find a similar result with medium and large LFP payments in California. A result suggesting our finding of charity hazard is not very strong. We did find evidence that lagged LFP payments significantly increase the marginal effects of participating in RI-PRF in three of the five states and in the combined model. These results support the opposite of charity hazard - LFP payments improve the probability of RI-PRF participation. A possible reason for this may be that producers are more informed about risks and government programs by participating in LFP. Nebraska was the only state without a significant response to lagged LFP payments.

We found statistically significant and positive impacts of lagged RI-PRF returns on RI-PRF participation for all models and all bins. A result indicating that counties previously enrolled in RI-PRF are more likely to continue to participate in RI-PRF then counties who did not previously enroll even if they had received a negative return. Our results show knowledge of RI-PRF contributes to participation into RI-PRF.

Table 4 reports the results of model 1 where the dependent variable is the percent of acres enrolled in RI-PRF. In this model, we only use counties with acres enrolled in RI-PRF for the current year. The constant represents a county in 2013 with zero LFP payments and not enrolled in RI-PRF the previous year.[7] Log of premium was significant in combined and three states- Nebraska, Oklahoma and Texas. The significance all differ in signs: combined (negative), Nebraska (negative), Oklahoma (positive), and Texas (negative). Negative and significant coefficients for log of premiums would follow neoclassical demand where the price increases, the quantity demanded decreases. Positive and significant coefficient could present the case of counties changing their participation into higher premium generating intervals and/or productivity factors. The log of wealth was found to be significant with differing signs in the selection model in two states: California (negative) and Oklahoma (positive). We found negative significant results for the year indicator in all models but two states – Kansas and Texas. Year indicator 2014 was found to be significant for the combined and all but one state - Oklahoma. Year indicator 2014 had differing signs where California was positive and the other significant models (combined, Kansas, Nebraska, and Texas) were negative. Year indicator 2015 was significant and differed in signs for two states: California (positive) and Nebraska (negative). Year indicator 2016 was significant and negative for two states: Oklahoma and Texas.

We found lagged LFP payments negative and significant in two states – California and Oklahoma. A result suggesting the presence of charity hazard in both California and Oklahoma. However, only Oklahoma had results consistent across bins, in that larger LFP payments were significantly and negatively influencing the probability of enrolling acres in RI-PRF. This result follows the conceptual model of charity hazard

[7] County fixed effects are not presented in the table, but available upon request.

in Figure 1. We also found evidence against charity hazard. For both the combined model and Texas, small, medium, and large lagged LFP payments increased the percent of acres enrolled in RI-PRF. No effect was found in Kansas and Nebraska. Our results provide evidence in support and against charity hazard in RI-PRF participation. As a result, we cannot definitively accept or reject our hypothesis that charity hazard exists in RI-PRF participation.

Lagged RI-PRF returns were found to be significant and negative in the combined model and Nebraska for the negative and between bins. A result suggesting that if the returns are not positive or large, the county is averse to enrolling.

Table 5 reports the results of model 2 where the dependent variable is liability per acre. Just like in model 1, we only consider counties with positive liability. The constant represents a county in 2013 with zero LFP payments and not enrolled in RI-PRF the previous year.[8] Year indicator 2014 was significant and positive for combined and three states- Kansas, Nebraska, and Texas. Year indicator 2015 was significant and positive for one state- Kansas. Year indicator 2016 was significant and negative for the combined and one state- Texas. We found significant and negative lagged LFP payments in Texas. Additionally, parameter estimates grew as the lagged LFP payment grew. As a result, Texas provides evidence of charity hazard. We also found the opposite of charity hazard in Oklahoma for all three bins and for one bin in Kansas (large lagged LFP). Results do not provide widespread support of charity hazard in lagged LFP payments on the amount of RI-PRF liability purchased.

[8] County fixed effects are not presented in the table, but available upon request.

Lagged RI-PRF returns are significant and negative for the between return bin in only one state- Oklahoma. Log of premium was significant and positive in combined and two states- Nebraska and Texas. Log of wealth is significant and negative in only one state- Oklahoma. A result suggesting decreasing risk aversion.

**Conclusions**

We empirically examined whether charity hazard exists between RI-PRF and LFP programs by estimating the demand for RI-PRF. A selection model was first estimated to focus on the probability of purchasing RI-PRF. Next, we used two dependent variables to measure the demand for RI-PRF insurance. The first variable (model 1), $RIPRF_{ct}$, is the percent of acres enrolled in RI-PRF. The second variable (model 2), $RILIA_{ct}$, is the amount of liability.

We did find evidence that lagged LFP payments significantly increase the marginal effects of participating in RI-PRF in three of the five states and in the combined model. These results support the opposite of charity hazard where LFP payments improve the probability of purchasing RI-PRF. In our other models, the results provide evidence in support and against charity hazard in RI-PRF participation. As a result, we cannot definitively accept or reject our hypothesis that charity hazard exists in RI-PRF participation.

We can also conclude that being enrolled in RI-PRF previously increases the likelihood of enrolling into the insurance in the future. Based on our selection model, counties who have been previously enrolled would continue enrolling compared to counties who have not enrolled at all. Premiums also show to have a positive and significant effect on the selection into RI-PRF insurance. Since RI-PRF gives the ability to select their own intervals for insurance, counties might be moving from growing season intervals with lower premium rates to winter months with higher premium rates. These increase the premiums paid, but the county is insuring for the whole year. Mandated disaster assistance only insures for the growing season, so the producer has an added protection for their growing season.

For further research, we would like to evaluate the actual returns from both programs to evaluate expected utility as a function of profit. Additionally, producer level data is needed for the analysis to reflect actual producer behavior. Data from farm-level producers, would also allow for evaluation of whether the government resources are being used efficiently and effectively. We would benefit from interval selections from producers and how those have changed from the introduction of LFP.

Another extension of this research could be to involve all livestock insurance programs as a whole. Since RI-PRF and LFP reflect insurance for feed costs for livestock producers, they are the most relatable programs.

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**Appendix**

**Table 1: Livestock Forage Disaster Program (LFP) Payment Statistics, $ per acre**

| Bins | Statistic | Combined | California | Kansas | Nebraska | Oklahoma | Texas |
|---|---|---|---|---|---|---|---|
| Overall | Mean | $11.08 | $4.30 | $17.11 | $22.19 | $21.61 | $4.87 |
| | Min | $0.001 | $0.04 | $0.001 | $0.02 | $0.003 | $0.002 |
| | Max | $131.47 | $42.09 | $79.72 | $131.47 | $103.30 | $40.84 |
| Small | Mean | $0.97 | $0.83 | $1.80 | $3.36 | $5.68 | $0.84 |
| | Min | $0.001 | $0.04 | $0.001 | $0.02 | $0.003 | $0.002 |
| | Max | $2.23 | $1.61 | $6.54 | $7.97 | $11.14 | $1.71 |
| Medium | Mean | $6.33 | $3.08 | $13.50 | $16.76 | $18.43 | $3.82 |
| | Min | $2.23 | $1.62 | $6.64 | $8.11 | $11.29 | $1.71 |
| | Max | $13.07 | $5.11 | $26.26 | $31.01 | $29.48 | $6.56 |
| Large | Mean | $28.84 | $10.24 | $39.61 | $51.91 | $43.93 | $11.01 |
| | Min | $13.08 | $5.11 | $26.49 | $33.01 | $29.61 | $6.63 |
| | Max | $131.47 | $42.09 | $79.72 | $131.47 | $103.30 | $40.84 |

Note: These bins were created by removing all of the zero LFP payments and then taking the bottom 25% of the payments for the small LFP payments, the middle 50% in the medium LFP payments, and the top 25% for large LFP payments of actual payments that were allocated.

**Table 2: Rainfall Index (RI-PRF) Returns from Insurance Statistics, $ per acre**

| Bins | Statistic | Combined | California | Kansas | Nebraska | Oklahoma | Texas |
|---|---|---|---|---|---|---|---|
| Overall | Mean | $2.03 | $3.12 | $2.42 | $3.11 | $1.49 | $1.49 |
| | Min | $-21.09 | $-5.35 | $-21.09 | $-15.03 | $-9.27 | $-9.73 |
| | Max | $91.76 | $12.49 | $48.44 | $91.76 | $28.37 | $55.78 |
| Negative | Mean | $-1.85 | $-0.43 | $-2.91 | $-2.27 | $-2.33 | $-1.31 |
| | Min | $-21.09 | $-5.35 | $-21.09 | $-15.03 | $-9.27 | $-9.73 |
| | Max | $-0.36 | $2.00 | $-0.39 | $-0.66 | $-1.12 | $-0.19 |
| Between | Mean | $1.22 | $4.42 | $1.25 | $0.98 | $0.92 | $1.19 |
| | Min | $-0.36 | $2.01 | $-0.37 | $-0.67 | $-1.06 | $-0.18 |
| | Max | $3.04 | $7.08 | $3.27 | $4.09 | $3.01 | $2.63 |
| Positive | Mean | $8.45 | $8.56 | $3.28 | $14.89 | $5.95 | $5.97 |
| | Min | $3.04 | $7.10 | $3.28 | $3.62 | $3.02 | $2.64 |
| | Max | $91.76 | $12.49 | $48.44 | $91.76 | $28.37 | $55.78 |

Note: After removing all the not enrolled acres, we created these bins by taking the bottom 25% of the returns for the negative return from insurance, the middle 50% in the between returns from insurance, and the top 25% for positive returns from insurance.

**Table 3. Selection Model Results**

| | Marginal Effects of Selection into RI-PRF | | | | | |
|---|---|---|---|---|---|---|
| | Combined | California | Kansas | Nebraska | Oklahoma | Texas |
| Variable | Parameter | Parameter | Parameter | Parameter | Parameter | Parameter |
| Year Indicator vs Year 2013 | | | | | | |
| 2014 | -0.101 *** | 0.032 | -0.066 | -0.155 *** | -0.215 *** | 0.001 |
| | -0.017 | -0.076 | -0.052 | -0.063 | -0.05 | -0.012 |
| 2015 | -0.013 | -0.081 | 0.022 | -0.015 | 0.044 | 0.009 |
| | -0.018 | -0.071 | -0.062 | -0.07 | -0.054 | -0.012 |
| 2016 | -0.051 *** | -0.231 ** | -0.066 | -0.078 | -0.141 ** | -0.003 |
| | -0.018 | -0.096 | -0.07 | -0.086 | -0.061 | -0.013 |
| LFP Payments Lagged vs Zero LFP Payments Lagged | | | | | | |
| Small | -0.007 | -0.195 ** | -0.048 | 0.051 | 0.118 | 0 |
| | -0.018 | -0.091 | -0.051 | -0.059 | -0.088 | -0.006 |
| Medium | 0.054 *** | 0.026 | 0.077 | 0.108 | 0.178 ** | 0.014 *** |
| | -0.015 | -0.084 | -0.05 | -0.107 | -0.088 | -0.006 |
| Large | 0.095 *** | -0.017 | 0.25 *** | 0.05 | 0.247 *** | -0.001 |
| | -0.022 | -0.07 | -0.07 | -0.106 | -0.097 | -0.013 |
| Return from RI-PRF Insurance Lagged vs Not Enrolled in RI-PRF Lagged | | | | | | |
| Negative | 0.342 *** | 0.581 *** | 0.354 *** | 0.302 *** | 0.442 *** | 0.122 *** |
| | -0.014 | -0.088 | -0.034 | -0.038 | -0.071 | -0.021 |
| Between | 0.415 *** | 0.513 *** | 0.469 *** | 0.393 *** | 0.601 *** | 0.145 *** |
| | -0.014 | -0.072 | -0.031 | -0.034 | -0.06 | -0.026 |
| Positive | 0.391 *** | 0.452 *** | 0.474 *** | 0.368 *** | 0.437 *** | 0.12 *** |
| | -0.021 | -0.069 | -0.08 | -0.057 | -0.094 | -0.026 |
| Log(Premium) | 0 | 0.497 | 0.031 | 0.071 *** | 0.149 *** | 0.048 *** |
| | -0.018 | -0.349 | -0.024 | -0.024 | -0.048 | -0.011 |
| Log(Wealth) | 0.034 | -0.138 * | 0.166 | -0.179 | 0.281 *** | 0.024 |
| | -0.029 | -0.082 | -0.102 | -0.119 | -0.091 | -0.015 |

Note: Parenthesis () indicates standard error. Single asterisk (*) indicates significance at the 10% level. Double asterisk (**) indicates significance at the 5% level. Triple asterisk (***) indicates significance at the 1% level

LFP is the Livestock Forage Disaster Payment. RI-PRF is the Rainfall Index Insurance for Pasture, Rangeland, and Forage. In the combined model, we used state fixed effects. The state fixed effects are available from the author by request.

**Table 4. Regression Model One Results**

| | | Dependent Variable: Percent of Acres Enrolled in RI-PRF | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Combined | | California | | Kansas | | Nebraska | | Oklahoma | | Texas | |
| Variable | | Parameter | | Parameter | | Parameter | | Parameter | | Parameter | | Parameter | |
| Year Indicator vs Year 2013 | | | | | | | | | | | | | |
| | 2014 | -0.041 | *** | 0.214 | *** | -0.017 | * | -0.094 | *** | -0.026 | | -0.045 | *** |
| | | -0.005 | | -0.053 | | -0.01 | | -0.016 | | -0.019 | | -0.007 | |
| | 2015 | -0.004 | | 0.16 | * | -0.004 | | -0.048 | * | -0.018 | | -0.009 | |
| | | -0.005 | | -0.09 | | -0.011 | | -0.025 | | (0.021) | | -0.008 | |
| | 2016 | 0.009 | | -0.144 | | -0.012 | | -0.035 | | -0.059 | ** | -0.02 | ** |
| | | -0.011 | | -0.461 | | -0.023 | | -0.038 | | -0.025 | | -0.03 | |
| LFP Payments Lagged vs Zero LFP Payments Lagged | | | | | | | | | | | | | |
| | Small | 0.025 | *** | -0.086 | | 0.004 | | 0.002 | | -0.031 | ** | 0.035 | *** |
| | | -0.006 | | -0.068 | | -0.011 | | -0.014 | | -0.014 | | -0.011 | |
| | Medium | 0.03 | *** | -0.101 | * | -0.005 | | -0.006 | | -0.056 | *** | 0.03 | ** |
| | | -0.006 | | -0.065 | | -0.011 | | -0.016 | | -0.016 | | -0.013 | |
| | Large | 0.02 | *** | -0.054 | | -0.008 | | -0.019 | | -0.062 | ** | 0.023 | * |
| | | -0.007 | | -0.065 | | -0.015 | | -0.021 | | -0.028 | | -0.014 | |
| Return from RI-PRF Insurance Lagged vs Not Enrolled in RI-PRF Lagged | | | | | | | | | | | | | |
| | Negative | -0.017 | ** | 0.023 | | -0.013 | | -0.039 | ** | -0.005 | | -0.011 | |
| | | -0.009 | | -0.037 | | -0.012 | | -0.016 | | -0.017 | | -0.012 | |
| | Between | 0.007 | | -0.024 | | -0.002 | | -0.042 | *** | 0.016 | | 0.018 | |
| | | -0.008 | | -0.041 | | -0.011 | | -0.016 | | -0.017 | | -0.012 | |
| | Positive | 0.008 | | -0.054 | | 0 | | -0.02 | | 0.009 | | 0.008 | |
| | | -0.008 | | -0.043 | | -0.023 | | -0.016 | | -0.015 | | -0.011 | |
| Log(Premium) | | -0.104 | *** | 0.8 | | -0.016 | | -0.103 | * | 0.026 | ** | -0.094 | ** |
| | | -0.029 | | -1.007 | | -0.042 | | -0.062 | | -0.011 | | -0.043 | |
| Log(Wealth) | | 0.009 | | 0.013 | | -0.013 | | 0.046 | | -0.079 | | 0.024 | * |
| | | -0.012 | | -0.046 | | -0.02 | | -0.072 | | -0.082 | | -0.013 | |
| | Constant | 0.063 | | 0.662 | | 0.188 | | -0.119 | | 0.953 | | 0.251 | * |
| | | -0.136 | | -0.887 | | -0.214 | | -0.773 | | -0.875 | | -0.146 | |
| | $R^2$ | 0.921 | | 0.893 | | 0.816 | | 0.719 | | 0.85 | | 0.935 | |

Note: Parenthesis () indicates standard error. Single asterisk (*) indicates significance at the 10% level. Double asterisk (**) indicates significance at the 5% level. Triple asterisk (***) indicates significance at the 1% level

LFP is the Livestock Forage Disaster Payment. RI-PRF is the Rainfall Index Insurance for Pasture, Rangeland, and Forage. County fixed effects are not provided, but available from author.

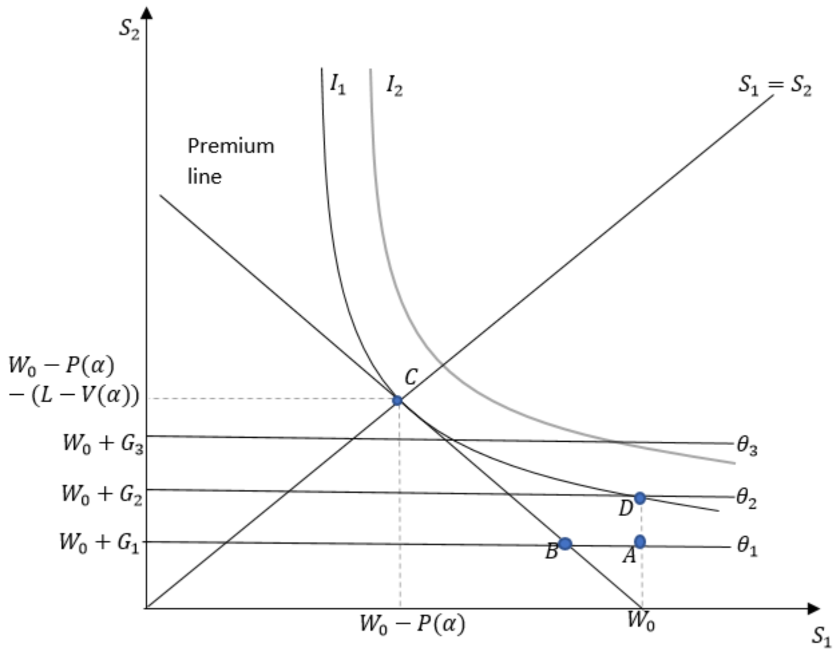
**Table 5. Regression Model Two Results**

| | | Combined | | California | | Kansas | | Nebraska | | Oklahoma | | Texas | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dependent Variable: Liability Per Acre | | | | | | | | | | | |
| Variable | | Parameter | | Parameter | | Parameter | | Parameter | | Parameter | | Parameter | |
| Year Indicator vs Year 2013 | | | | | | | | | | | | | |
| | 2014 | 3.38 | *** | -1.284 | | 14.928 | ** | 14.386 | ** | -1.148 | | 3.284 | ** |
| | | -1.067 | | -2.461 | | -6.902 | | -6.823 | | -7.466 | | -1.584 | |
| | 2015 | -0.414 | | 0.314 | | 15.454 | * | 7.99 | | -0.425 | | -1.54 | |
| | | -1.091 | | -4.205 | | -8.206 | | -8.764 | | -6.604 | | -0.993 | |
| | 2016 | -9.369 | *** | 5.482 | | 8.595 | | -4.831 | | 10.544 | | -10.316 | *** |
| | | -1.381 | | -21.583 | | -14.32 | | -10.519 | | -23.401 | | -3.691 | |
| LFP Payments Lagged vs Zero LFP Payments Lagged | | | | | | | | | | | | | |
| | Small | 2.179 | | -0.7 | | -8.383 | | 7.59 | | 20.001 | *** | -3.881 | ** |
| | | -1.406 | | -3.184 | | -6.371 | | -6.312 | | -6.413 | | -1.683 | |
| | Medium | 0.804 | | 2.65 | | -0.833 | | 2.691 | | 24.833 | *** | -5.158 | ** |
| | | -1.343 | | -2.643 | | -7.066 | | -6.834 | | -6.923 | | -2.159 | |
| | Large | -1.44 | | 1.591 | | 16.468 | * | -0.062 | | 18.837 | *** | -5.938 | * |
| | | -1.611 | | -3.04 | | -9.099 | | -9.08 | | -7.364 | | -3.189 | |
| Return from RI-PRF Insurance Lagged vs Not Enrolled in RI-PRF Lagged | | | | | | | | | | | | | |
| | Negative | 2.088 | | -2.676 | | -8.131 | | 10.288 | | -3.337 | | 6.163 | |
| | | -1.956 | | -1.751 | | -7.278 | | -7.095 | | -5.08 | | -8.584 | |
| | Between | 0.65 | | -1.486 | | -3.662 | | 1.546 | | -8.359 | *** | 5.465 | |
| | | -1.768 | | -1.94 | | -6.751 | | -7.139 | | -3.312 | | -8.344 | |
| | Positive | 0.214 | | -0.613 | | 0.499 | | 7.468 | | -6.198 | | 8.927 | |
| | | -1.756 | | -2.032 | | -6.879 | | -6.781 | | -3.8 | | -8.474 | |
| Log(Premium) | | 42.544 | *** | 3.849 | | 22.605 | | 50.321 | *** | 19.628 | | 54.365 | *** |
| | | -1.117 | | -47.147 | | -25.673 | | -3.468 | | -39.16 | | -16.681 | |
| Log(Wealth) | | -1.469 | | 1.049 | | 8.024 | | -33.863 | | -32.888 | * | 3.625 | |
| | | -2.729 | | -2.17 | | -12.668 | | -31.547 | | -19.908 | | -3.894 | |
| | Constant | 4.528 | | 2.886 | | -52.365 | | 336.952 | | 340.225 | | -36.459 | |
| | | -30.453 | | -41.505 | | -135.679 | | -337.684 | | -214.865 | | -43.52 | |
| | $R^2$ | 0.91 | | 0.653 | | 0.66 | | 0.877 | | 0.911 | | 0.859 | |

Note: Parenthesis () indicates standard error. Single asterisk (*) indicates significance at the 10% level. Double asterisk (**) indicates significance at the 5% level. Triple asterisk (***) indicates significance at the 1% level

LFP is the Livestock Forage Disaster Payment. RI-PRF is the Rainfall Index Insurance for Pasture, Rangeland, and Forage. County fixed effects are not provided, but available from author.

Figure 1: Tradeoff between Insurance and Government Relief



Chapter 2: Risk Implications from the Selection of Rainfall Index Insurance Intervals

## Introduction

Since the passage of the 1994 Crop Insurance Reform Act, the federal crop insurance program has grown in both size and scope. The program progressed from generating under $1 billion in premiums in 1994 to generating nearly $9.3 billion in 2016 (USDA-RMA 1994, 2016c). In 2007, the federal crop insurance program introduced the Rainfall Index (RI) and Vegetation Index (VI) Insurance Pilot Program for Pasture, Rangeland, and Forage (PRF) in selected states. In 2016, RI-PRF replaced VI-PRF and was made available in all 48 contiguous states enrolling 28,538 policies and providing over a billion dollars in coverage on more than 52.3 million acres (USDA-RMA 2016c). However, insured acreage represents only about 8% of the total 649.5 million acres of pasture and hay land. This small percent of coverage contrasts greatly to corn, where 87% of acres were insured in 2016 (USDA-RMA 2016d).

RI-PRF is constructed as an index; therefore, it contains “index based” benefits to the insurer (i.e., minimizing information asymmetry held by the insured). The insurer designer must minimize basis risk (the risk uncovered by the index), while attempting to maintain contract transparency, containing delivery, marketing, and reinsurance costs (Miranda and Farrin 2012). A key feature making RI-PRF unique from other index based insurance products is that the insured selects the protected time frame (i.e., insurance intervals). Insurance intervals across different months open the door for different levels of basis risk between forage production and precipitation as well as the insured to select contracts with impacts the Federal Crop Insurance Corporation never intended. As a result, RI-PRF insurance intervals may perhaps contain different levels of basis risk, possibly at values higher than anticipated, which could result in a misallocation of government resources (i.e., subsidies).

In this paper, we empirically examine the financial outcomes from forage production and RI-PRF insurance participation in two locations in Nebraska. Both locations provide historical forage production and precipitation data, allowing us to examine the relation between RI-PRF indemnities and forage production. Specifically, we focus the decision by the government to allow the insured to select the insurance interval. We examine how the insurance intervals impact producer expected net income and net income risk, and government program cost. Results from our analysis can help policymakers improve the effectiveness of RI-PRF insurance.

This article proceeds as follows. We first provide a review of index based insurance followed by a description of the RI-PRF insurance program. We then introduce the conceptual model with a description of the data, methods and empirical analysis. Findings are presented and interpreted in the results section, with conclusions in the last section.

**Index Based Insurance**

When purchasing insurance, risk faced by the producer declines as net income becomes less variable due to indemnities being paid during low yield events and premiums being paid (no indemnities) during high yield events. However, if the index is loosely related to yields then risk may not always be reduced. To the government, if yields are loosely related to the index would go against their goal of providing an effective risk management program.

Previous literature has identified both advantages and disadvantages of index based insurance. Benefits exist from the fact that index insurance minimizes the incidence of opportunistic behavior stemming from moral hazard and/or adverse selection (Miranda 1991). Miranda (1991) documented that the primary concern with index insurance is that the relation between indemnity payments and actual production are not entirely dependent on each other, i.e., basis risk. Norton, Turvey, and Osgood (2012) found that the strongest correlation of index insurance payouts occurred when there was minimal distance between the index and the farm. Mobarak and Rosenzweig (2013) found that the closer the weather station to the production site, the smaller the basis risk between precipitation and production. Norton, Boucher, and Chiu (2015) found that index insurance based on multiple weather station data reduced basis risk. Conradt, Finger, and Bokusheva (2015) found that index insurance contract design, specifically Quantile Regression, can improve the relation between yields and the index. As a result, index insurance will not always provide indemnities when a production loss is experienced; whereas, traditional multi-peril crop insurance provides indemnities when there is a loss (Smith and Watts 2009; Kang 2007). Rainfall indexes typically have greater basis risk than yield based indexes (Smith and Watts 2009). Precipitation represents only one factor impacting forage production (Dahl 1963; Sims and Singh 1978) and other perils can influence production.

Since 2007, when RI-PRF was introduced as a pilot program, research has focused on the various features of the program. For example, Nadolnyak and Vedenov

(2013) found that a higher correlation between the rainfall index and yield improves welfare by lowering risk. Ifft, Wu, and Kuethe (2014) focused on the impacts of PRF insurance on farmland values and reported that the availability of the insurance increases pastureland values by at least 4%. RI-PRF literature is thin, but valuable insights can be gained from other index insurance research evaluating precipitation or rainfall. For example, Müller et al. (2011) examined rainfall as part of the production of green biomass, stating that rainfall index insurance took away from “natural insurance”, taking care of the land as if it were never insured, when the trigger level is high. Similar to RI-PRF insurance, Maples, Brorsen, and Biermacher(2016) evaluated rainfall index pilot program for annual forage production and found the index to be well designed with a high correlation between the index and rainfall.

Correlation analysis has historically been the metric used to evaluate the effectiveness (level of basis risk) of index based insurance. Clarke (2016) provides a good explanation on how the value of an index insurance product will be dependent on the correlation between index and insured loss. For a thorough review of index based insurance using correlation analysis see Smith and Watts (2009). Along with their thorough review, Smith and Watts (2009) identify research where correlations between precipitation and biomass vary from a low of .026 (forage production in Sahel area of Africa) to a high of 0.80 (grass production in New Mexico) with an average of 0.60. Since Smith and Watts (2009), additional research has evaluated index insurance also using correlation analysis (Norton, Turvey, and Osgood 2012; Mobarak and Rosenzweig 2013; Norton, Boucher, and Chiu 2015; Maples, Brorsen, and Biermacher 2016). Correlation identifies the strength of the relation between two variables and in index insurance the two variables are generally the index and yield (or possibly the same parameter the index is measuring at the farm, such as precipitation). While correlation measures are useful, they can provide an incomplete picture. Our approach of evaluating financial outcomes through the use of the variance of net income from RI-PRF interval selection allows for a more precise identification of the financial risk reducing effectiveness of RI-PRF interval selection because purchasing an insurance contract must lower the variance of net income through indemnities being greater than premium in low production years and a premium cost in high production years.

**RI-PRF Program**

RI-PRF represents a single peril (precipitation) index insurance product focusing on the production of perennial forages on rangeland, pastureland, and cropland.[9] The objective of RI-PRF is to provide perennial forage producers revenue (indemnities) due to losses in precipitation. RI-PRF differs from the traditional index insurance by insuring precipitation over a specific period (two-month intervals) versus production at some aggregate level (typically county). Additionally, the producer is able to choose under which practice they would insure their forage, either haying or grazing. If the producer uses land for both, the producer would choose which practice is most beneficial to them based on their own risk preferences. The current study analyzes the haying option.

[9] While the Risk Management Agency (RMA) uses the term rainfall in the title of the insurance product, they are actually measuring precipitation from the National Oceanic Atmospheric Administration Climate Prediction Center (NOAA CPC). Rainfall and precipitation are used interchangeably in this manuscript to describe precipitation in the form of rainfall, snow, sleet, and other forms.

To be eligible for RI-PRF, the producer is required to have a share on insurable acreage that was in production before July 1 prior to the coverage year. RI-PRF offers a variety of contracts based on varying coverage levels and productivity factors. Coverage levels are chosen from 70%, 75%, 80%, 85%, and 90% varying by county and production type. Productivity factors vary from 60% to 150% of county base value in 1% increments. The productivity factor allows producers to adjust forage value, in dollars per acre, based on their specific land productivity. For example, a producer who finds their land to be of highest value relative to the county base level would choose 150% productivity factor (USDA-RMA 2016a). RI-PRF insures by grids: 0.25 degrees latitude by 0.25 longitude at the equator, which translates into grids of about 17 by 17 miles. Grids were created by the National Oceanic Atmospheric Administration Climate Prediction Center (NOAA CPC) and do not follow geopolitical boundaries, with some grids being uninsurable. The gridded precipitation data represents an interpolated value based on the entire grid and cannot be traced to a single point or reporting station. An expected grid index is calculated for each grid and index interval using long-term, historical, gridded precipitation data (USDA-RMA 2015c). RI-PRF requires the producer to insure monthly precipitation using two-month intervals. The two-month interval rule results in eleven insurance intervals during the calendar year: January-February, February-March, March-April, April-May, May-June, June-July, July-August, August-September, September-October, October-November, and November-December. RI-PRF rules require that producers must insure at least two intervals and intervals cannot overlap (i.e., cannot insure January-February interval and February-March interval) effectively limiting the maximum number of intervals to six. Intervals are weighted with a minimum weight of 10% and a maximum weight of 60% requiring the sum of weights to add up to 100%. Losses are calculated based on whether the current year's precipitation in a grid has deviated from the historical normal precipitation in the same grid, for the same interval. An indemnity will be paid if

(1) $$Payment\ calculation\ factor = \frac{(Trigger\ grid\ index - Final\ grid\ index)}{Trigger\ grid\ index} > 0$$

where the trigger grid index is equal to the insured's coverage level multiplied by the expected grid index and the final grid index represents NOAA's interpolated current year gridded precipitation data or successor data for each grid ID and index interval (USDA-RMA 2015c). Expected grid index or expected precipitation is the mean accumulated precipitation by both grid and insurance interval, calculated using NOAA's interpolated historical gridded precipitation or successor data and expressed as a percentage with mean equal to 100 (USDA-RMA 2016a).

The size of the indemnity depends upon the size of the policy protection per unit – calculated as

(2) $$Policy\ protection\ per\ unit$$
$$= Insured\ acres * producer\ share * Dollar\ amount\ of\ protection$$

where insured acres identify the size of the insured area, producer share identifies the forage share belonging to the producer, and dollar amount of protection is calculated as

$$(3) \qquad Dollar\ amount\ of\ protection$$
$$= County\ base\ value * Productivity\ factor * Coverage\ level$$

where county base value represents the forage value in the county and is determined by the RMA (USDA-RMA 2016a).

Indemnity is then calculated as

$$(4) \qquad Indemnity = Payment\ calculation\ factor * Policy\ protection\ per\ unit$$

The Federal Government subsidizes the premiums for RI-PRF, which have not changed since the introduction of the pilot program. The 70% and 75% coverage levels are subsidized at 59% of the premium. For coverage levels of 80% and 85%, 55% of the premium is subsidized. Lastly, for 90% coverage level, 51% of the premium is subsidized.

**Conceptual Model**

Our conceptual model modifies Maples, Brorsen, and Biermacher (2016), by allowing monthly insurance interval selection in a perennial forage system. We assume producers are risk averse, expected-utility maximizers and can choose to purchase insurance. If producers insure, they are able to select from a portfolio of contracts based upon coverage level, productivity factor, and insurance intervals. Expected utility is written as

(5)
$$\max_{\substack{A\in\{0,1\}\\ 70\le\delta\le 90\\ 60\le\varphi\le 150\\ \alpha\in\{1,11\}}} EU(\pi) = \iint U(\pi)\mathrm{f}(\theta)d\lambda dY$$

$$\mathrm{s.t.}\,\pi = \mathrm{PY} + \mathrm{A}\left(k(\max((\delta - F)/\delta, 0)) - c(\delta,\varphi,\alpha)\right) - \mathbf{r}'\mathbf{z}$$

$$\theta = [\lambda, Y]$$

$$k = B(\alpha)\delta\varphi$$

$$U'(\pi) > 0, U''(\pi) < 0$$

where $EU(\pi)$is expected utility of net income, *P* is the price for each unit of production, λ represents RI-PRF index insurance policy , *Y* is production per unit, *A* is a discrete choice variable equaling 1 when a producer chooses to insure and 0 if the producer does not insure, α reflects the chosen insurance interval (minimum of two and maximum of six) out of the 11, *k* is the policy protection per unit, *B* is the county base value dependent upon the insurance interval, δ is the trigger grid index, *F* is the final grid index, $\varphi$ is the productivity factor adjustment, *c* represents producer insurance premium, *r* is a vector of other input costs, *z* is a vector of other inputs, θ represents the joint distribution of the index value and production and U' (π) and U" (π) are the first and second derivatives of the net income function. The monthly interval weights have been left out for simplicity in the equation, but not in the analysis.

Our primary objective is to focus on the risk reducing aspects of different insurance intervals, $\alpha$. As a result, we focus on evaluating producer net income and risk (measured as variance of net income) by comparing multiple insurance intervals to no insurance. Each insurance interval will likely have a different relation (basis risk) between observed production and return from insurance participation and, therefore, a different impact on the variance of net incomes. The impact on variance of net incomes identifies the risk reducing aspects of RI-PRF insurance intervals. A low relation between production and net income from a specific insurance interval can do one of two things. First, it can cause a producer who experiences low production to pay a premium without an indemnity, lowering net income even further than if there were no insurance. Second, it could cause a producer who experiences high production to receive a large indemnity thereby increasing net income further than without insurance. In either one of these cases, the variance of net income would increase rather than decrease. A properly functioning insurance contract would reduce the variance of net income. A strong relation between precipitation and forage production would imply insurance payments when a low production event is observed, thereby reducing producer net income risk. Because RI-PRF insurance intervals are expected to reduce risk, the hypothesis would be rejected by empirical evidence that insurance intervals generate higher variance than not purchasing an RI-PRF insurance policy (i.e., no insurance).

To further explain our approach, Figure 1 displays the change in risk versus reward when purchasing a subsidized index insurance policy. Point A represents the producer with no insurance. At this point the producer would face *R* returns and *X* risk. Purchasing insurance will cause the producer to move into one of the four quadrants.

Zones I and IV represent outcomes where the subsidized insurance is not working correctly and producer returns are lower than expected. Zone I portrays a traditional insurance contract where the producer pays a premium, in order to reduce risk, thereby lowering returns. Zone IV shows the region where a premium paid results in a reduction in returns but risk increased.

Zones II and III represent outcomes with subsidized insurance working properly. In Zone II and Zone III the producer paid a subsidized premium therefore seeing increased returns over time compared to no subsidized insurance. Zone II is a subsidized and well-functioning insurance markets as risk was also reduced. Outcomes in Zone III imply a subsidy transfer but not a reduction in risk. Outcomes in Zones III or IV, lead to an increase in risk, violating RMA's stated goal of an effective risk management program.

**Data**

Data were obtained from two University of Nebraska-Lincoln research ranches, one located in the central Sandhills and the other in the eastern Sandhills of Nebraska. The two research ranches are operated to reflect actual ranch production practices and management. The first site is the Gudmundsen Sandhills Laboratory (GSL), located in Grant, Hooker, and Cherry counties. Data from GSL range from 2004 to 2015. The second site, Barta Brothers Ranch (BBR), is located approximately 140 miles to the east of GSL in Rock and Brown counties. Data from BBR is from 2001 to 2015. Both sites represent upland Sandhills rangeland dominated by a mixture of native warm-season grasses and cool-season grasses along with common prairie forbs and shrubs (Schacht et al. 2000). The Sandhills represent 95% of all rangeland in Nebraska, where the predominate use is for livestock (Adams et al. 1998). Each research site had on-site weather station that provided daily precipitation values which were aggregated up to monthly values for evaluation.

Along with the precipitation data, each site had detailed information on annual forage production from pastures in a simple rotational grazing system. Exclosures, an area to keep unwanted animals out (1.2 x 1.2m wire panels), were placed randomly in pastures at each site; there were 36 exclosures at GSL and 60 exclosures at BBR. Exclosures were moved to a new location at the beginning of each year in order for vegetation in exclosures to represent plant production of an area that had been harvested in previous years. In our semi-arid environment in mid-August, both cool season and warm season grasses have reached maturity. These grasses were hand-clipped at ground level in a 0.25m x 1.0m area placed within the exclosure. All herbaceous material was separated in functional groups consisting of warm-season grasses, cool-season grasses, sedges, and forbs. Current year's growth of shrubs (i.e., leaves and new stem tissue) was collected from plants rooted within the quadrats. Standing dead plant material and litter were also collected. All separated plant material was placed in paper bags, oven dried (60°C) to a constant weight, and then recorded.

Our data comes from a relatively short time period of 12 years at GSL and 15 years at BBR. As a result, it is possible that our results could be due to differences in our time period. As a result, we plot our historical farm and county forage yield (1978 to 2014USDA-National Agricultural Statistics Service (NASS) county hay yield excluding alfalfa) for both locations and calculate the Pearson correlation coefficient. Plots are presented in Figure 2. Strong correlation was found to exist between farm and county production for both locations with correlation coefficients of 0.69 at GSL and 0.81 at BBR.

Hay price was based off of the USDA-NASS annual hay price excluding alfalfa for the state of Nebraska (USDA-NASS 2016a). The average yearly price in 2015 was $0.03975 per pound of hay, and we assumed the same price for all years to not add unnecessary noise to the model.

**Methods**

We first identify whether a relation exists between farm precipitation and farm production by formulating and evaluating a precipitation response equation. This helps identify whether precipitation is a good predictor of forage production or not in our study area. The forage response from precipitation may not be monotonic, therefore a linear relation between precipitation and production may not be appropriate (Azzam and Sekkat, 2005). Following Azzam and Sekkat (2005), we describe the relation between precipitation and yields using a gamma curve. Forage production, $Y_{ijt}$, for a specific exclosure *i* (*i*=1,...,Z)[10] at location *j* (*j* = 0,1) in year *t* (*t*= 1,…,12 or 15 (depending upon location)) is specified as a function of annual precipitation ($R$) and dummy variable for location ($D$):

(6) $$Y_{ijt} = ke^{-\delta R_{jt}} R_{jt}^{\rho} + \gamma D_j \text{ where } \delta > 0 \text{ and } \rho > 0$$

where $k, \delta, \rho$ are the scalar, rate, and shape parameters to be estimated and $\gamma$ is the parameter for the location dummy variable. Location controls unobserved fixed effects

[10] Z represents the number of exclosures ranging between 36 and 60, depending upon location and year.

from geographic heterogeneity in local weather and other factors. To estimate equation (6) we take the log of the gamma curve. STATA 13.1 was used for the estimation.

From our conceptual framework, we evaluate the risk reducing impacts of RI-PRF. Our evaluation is derived from the theory that producers are risk averse and seek to maximize expected utility. Additionally, the insurance provider offers an insurance product which is intended to reduce risk. The presence of the subsidy provides the opportunity for indemnities to be greater than producer paid premiums.[11] Our hypothesis, that RI-PRF insurance intervals are an effective risk management tool, would be rejected if net income risk is found to increase (Figure 1, Zone III and Zone IV).

With many different RI-PRF contract combinations available to producers we identified and evaluate six different insurance scenarios making sure we take into account precipitation extremes (low and high precipitation, discussed in detail below) and personal correspondence with producers.[12] Using expected monthly precipitation at the farm for each location we categorized months into three precipitation categories: low, high, and medium, Figure 3. As illustrated in Figure 3, the low precipitation category includes: November, December, January, February, and March. The high precipitation category includes: April, May June, July, and August. The medium precipitation category includes September and October. With only two medium precipitation months and RI-PRF requiring a minimum of four months we are unable to evaluate the medium

[11] With insurance being rated so that over a sufficient amount of time: premium = indemnity so that the loss ratio (indemnity/premium) = 1. The subsidy effectively increases producer return by lowering premiums so that the loss ratio > 1.

[12] Our approach of examining precipitation extremes allows us to greatly lower the number of scenarios evaluated.

precipitation category exclusively. We evaluate two high precipitation insurance scenarios with one being early in the growing season (high early) and one later in the growing season (high late) and one low precipitation insurance scenario. We evaluate three other scenarios which are a blend of precipitation categories. These three scenarios are: low/high, high/medium/low, and medium/low.[13]

In order to specifically analyze the risk reducing effectiveness of different insurance scenarios, we evaluate yearly returns from insurance scenarios at each location, holding coverage level, productivity factor, and output prices constant. Each of the scenarios selected was insuring hay production at the 90% level, with a 100% productivity factor. We chose the coverage level to insure the highest amount of precipitation. The productivity factor was chosen so that the dollar amount of protection approximated the expected value of production compared to the county based production values.[14]

RI-PRF insurance period is based on the calendar year, not on the forage production year. As a result, a producer buying RI-PRF could select insurance periods which effectively would be insuring the following year's production. Because we are interested in evaluating the risk reducing aspects of RI-PRF, we moved the insurance period to start September 1. This modification allows us to correctly link insurance periods to the production year.

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[13] The following are the interval selections for each scenario: Low represents Jan/Feb and Nov/Dec; Low/High represents Jan/Feb and May/Jun: High Early represents Apr/May and Jun/Jul: High Late represents May/Jun and Jul/Aug; High/Medium/Low represents Aug/Sep and Oct/Nov; and Medium/Low represents Sep/Oct and Nov/Dec.

[14] Both 150% and 60% productivity factors were evaluated to identify the influence of the productivity factor on net income.

The RMA offers insurance to protect producers against sufficiently large losses in production (or revenue when prices are insured). For each evaluated insurance scenario and no insurance, we evaluated total net income. To identify the reduction in risk we calculated the variance from each insurance contract combination and compared them to no insurance.

## Results

Average monthly precipitation for both GSL and BBR are presented in Figure 3.[15] Results indicate large variation in average historical monthly precipitation with November through March exhibiting low precipitation values and April through August with high precipitation. For GSL, average precipitation varied from a low of 0.26 inch in December to a high of 4.37 inches in June. For BBR, results were similar, with the low being 0.39 inch in January to a high of 4.32 inches in June. Recall that in RI-PRF each insurable interval's trigger grid index is expressed as a percentage with mean 100. With a 90% coverage level (or a 10% deducible), precipitation at GSL in November/December interval would need to drop 0.058 inch to trigger a payment. For a May/June interval, precipitation at GSL would need to drop 0.763 inch, which happens to be more than the expected precipitation in November/December interval. Insuring precipitation declines greater than 0.058 inch is substantially different than insuring precipitation declines greater than 0.763 inch.

[15] RI-PRF weather station monthly precipitation is unavailable. With both locations displaying similar monthly average precipitation totals, it is likely that RI-PRF weather station data exhibit similar patterns.

Interval premium rates by location are presented in Table 1. While the policy protection per unit is the same across both locations and interval, the premium rates differ greatly. For BBR, the premium rate per $100 of coverage at the 90% coverage level varied from a low of $12.37 in May/June interval to a high of $25.84 in November/December interval.[16] Production months during high expected precipitation have a smaller premium rate; whereas other months, such as low expected precipitation months, reflect a larger premium rate. With the subsidy being applied as a percentage of premium, the difference between producer paid premium rates in production months and non-production months becomes smaller. The subsidy effectively makes it more appealing (i.e., more subsidy dollars per acre) for producers to insure during the months with higher premium rates. For example, using GSL location, insuring November/December interval provides $10.17 in subsidy per acre whereas insuring in May/June interval provides less than half of the subsidy dollars or $4.93 in subsidy per acre.

Forage production parameter estimates from the regression model, equation 6, are reported in Table 2. Estimated coefficients in the regression model were found to be significant for the scalar, rate and location dummy. Thus, precipitation was found to be a good predictor of forage production. The location dummy variable was significant and negative with BBR expecting 202.24 fewer pounds of forage than GSL. The $R^2$ value of

[16] The maximum and minimum premium rates at the 90% coverage level are identical between both BBR and GSL locations. Premium rates were different for other insurance intervals and coverage levels.

0.72 indicates our precipitation model accounts for a substantial amount of variation in forage production.[17]

Table 3 provides a historical view of annual production deviation from predicted production ((actual production- expected production)/ expected production), actual production and RI-PRF insurance net returns from insurance participation (indemnity-premium) from the six different insurance scenarios at both locations taking into account precipitation extremes and personal correspondence with producers. We calculated yearly returns from insurance using current RI-PRF premiums and calculating indemnities by identifying precipitation compared to the trigger index (RMA 2016a). At GSL, forage production was higher than expected in eight out of twelve years. At BBR, higher forage production was observed in ten out of fifteen years. At both GSL and BBR, all insurance scenarios had positive average net returns over their respective study period which is not surprising given a 51% premium subsidy associated with the 90% coverage level. The top two highest average net returns at GSL were found in the medium/low and the low insurance scenario with average net returns of $9.01 and $7.59 per acre, respectively. For BBR, the top two highest average net returns were found in the low ($15.30) and low/high ($10.78) insurance scenarios. In both locations, we find highly variable net returns from the different insurance scenarios with a positive or negative deviation from predicted production. In 2006, for instance, at the GSL location, actual production was 11% higher than expected; however, all insurance scenarios generated a positive net return per acre. At the GSL location, a 36% production loss was

[17] Graph of the residuals and expected values indicated randomness.

experienced in 2009 and all insurance scenarios paid more in premiums than were paid back in indemnities, a result indicating the worst outcome for a producer, paying insurance premiums and experiencing a large production shortfall. For BBR, their largest deviation was in 2001, with an 82% production loss, and for all but one (high/medium/low) insurance scenarios premiums were greater than indemnities. The opposite result was found in 2012 where actual production was 128% higher than expected and all insurance scenarios except high/medium/low resulted in very large net returns.

Forage production expected net income from no insurance and the six insurance scenarios are presented in Table 4. For each year, we calculate net income as revenue from production plus indemnity minus producer paid premium (subsidy removed). Net income for no insurance is simply revenue from forage production for the specific year. Figures 4 (GSL) and 5 (BBR) graphically portray averages and variances from no insurance and the six insurance scenarios from Table 4. Results indicate that average net income from all insurance scenarios are greater than no insurance in both locations.[18] This is an expected result given producers' premiums being subsidized. To determine whether the intervals in the scenarios are working as intended to reduce risk, we examine the variance of net income. An increase in variance indicates intervals are not working as intended. Results indicate that variance increases and decreases, depending upon the insurance scenario and location.

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[8] The high early insurance scenario at Gudmundsen increases the return by a negligible amount of $0.05 per acre.

At GSL, we find three insurance scenarios, high early, high late, and medium/low reduce net income risk over no insurance. The high early insurance policy results in the largest decline in risk. We find three insurance scenarios lead to increases in risk: low/high, high/medium/low, and low. The low insurance scenario leads to the largest increase in risk and comes from intervals with low expected precipitation. Additionally, the low insurance scenario provides the second highest net income, behind the medium/low insurance scenario. The medium/low insurance scenario provides the highest net income while slightly lowering risk to the producer. Under current RMA rules that uses a calendar year, in order to insure in the medium/low (fall season months) insurance scenario, the producer would forego any insurance benefits in the current forage production year so they can insure the following year's production. The result that medium/low insurance scenario, which occurs during the fall, reduces risk suggests that the RMA should consider moving the insurance period to follow the forage production year instead of the calendar year. From the perspective of the risk averse producer they would select insurance scenario between the three risk reducing options. Producers with low levels of risk aversion could select medium/low insurance scenario and a highly risk averse producer would select high early insurance scenario.[19] From the perspective of the RMA in that they are mandated to provide an effective risk management program they would discontinue all risk increasing scenarios. As a result, the medium/low insurance scenario would disappear due to low insurance scenario intervals no longer being

[19] As a robustness check, we estimated the maximum (150%) and minimum (60%) productivity factors and found similar results. All scenarios except two stayed in their original risk zone and none moved to a lower expected return (zones I and IV). At GSL, high/late 150% productivity factor moved from risk reducing to increasing and high/medium/low moved from risk increasing to reducing.

available. Producers would then choose between high early and high late insurance scenarios.

For BBR we again find three insurance scenarios reduce risk (high early, high late, low/high) and three that increase risk (low, high/medium/low, and medium/low). The low/high insurance scenario provides the highest reduction in risk and the second highest increase in expected income. The low insurance scenario provides the highest increase in expected income; however, it also increases risk. At BBR, the risk averse producer would always select low/high insurance scenario because it provides the lowest risk at the highest expected income. It should be noted that high late and high early insurance scenarios are close in proximity to low/high insurance scenario. From the perspective of the RMA they would discontinue the three risk increasing insurance scenarios. Additionally, dropping the low insurance scenario removes the incentive to maximize insurance returns, saves RMA the most subsidy dollars since this scenario results in the highest total premium. As a result of dropping risk increasing scenario, the low/high insurance scenario would disappear due to low insurance scenario intervals no longer being available. Producers would then choose between the risk reducing high early insurance scenario and high late insurance scenario.

Results indicate that low and high/medium/low insurance scenarios were risk increasing at both locations. The medium/low insurance scenario switches from risk reducing at GSL to risk increasing at BBR. The low/high insurance scenario changes from risk increasing (slightly) in GSL to risk reducing in BBR. Changes in the effectiveness of risk management between locations provide insights into differences in risks faced by different locations as well as the functionality of RI-PRF. Note that dropping low scenario intervals makes risk reducing scenarios identical between both locations.

## Conclusions

In this paper, we investigated the relation between RI-PRF interval selection and forage production at two locations in Nebraska. Our primary goal was to examine whether RI-PRF insurance intervals selection provide an effective risk management program. Our findings help insurance agents and policy makers improve RI-PRF insurance in order to provide desired outcomes.

Risk was assessed by evaluating the change in the variance of net income when purchasing insurance with different insurance intervals. Our finding suggest risk increasing insurance intervals exist at both locations. We also found one insurance scenario (low in BBR) that provided the highest net income while increasing risk, suggesting a profit maximizing opportunity. Dropping risk increasing intervals removes the one identified case where profit maximizing behavior was found.

Our results indicate RI-PRF reduces net income risk with intervals insuring during high expected precipitation (growing season); while net income risk increases with intervals insuring low expected precipitation (non-growing season, winter months). As a result, we are unsure whether it is the growing season or size of expected precipitation contributing to insurance interval effectiveness. There is no doubt that the value of expected precipitation influences the precipitation deviation, indemnity and expected production. Rainfall during winter months will not contribute to crop growth if it evaporates or drains away, which is especially true on the sandy soils that are found on the ranches evaluated in this study. Recall, that a drop of only 0.058 inch would trigger an indemnity at GSL during November/December interval whereas in May/June interval the drop would need to exceed 0.763 inch. It could be possible that in some locations a small drop in precipitation could impact production, if it was during the growing season. Insuring during the growing season appears logical because insurance results indicate the strongest decline in net income risk. Future research could help shed the light on whether amount of expected precipitation or the season contributes more or less to the risk reducing effectiveness of RI-PRF insurance.

While we find no risk management benefits from insuring during the low expected precipitation intervals, which are during the winter, for these two locations in Nebraska, locations farther south in the U.S. may have benefits due to different expectations on monthly precipitation and the growing season occurring earlier in the calendar year.

Our findings suggest that insurance in the medium/low scenario at GSL lowers risk. With RI-PRF insurance operating on a calendar year and forage production following a plant production year, it is difficult to insure the medium/low scenario because it insures during fall expected precipitation, which would be past the upcoming production year. Moving the insurance period to correspond with the forage production year would overcome this obstacle. Identifying the correct plant production year in each region would be paramount in developing a more complete insurance product.

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**Appendix**

**Table 1: Insurance Premiums for Both Locations**

| Location | Intervals | Policy Protection Per Unit | Premium Rate Per $100 | Total Premium | Premium Subsidy | Producer Premium |
|---|---|---|---|---|---|---|
| GSL | Jan/Feb | $74 | 25.24 | 18.68 | 9.53 | 9.15 |
| | Feb/Mar | $74 | 20.91 | 15.47 | 7.89 | 7.58 |
| | Mar/Apr | $74 | 16.71 | 12.37 | 6.31 | 6.06 |
| | Apr/May | $74 | 13.71 | 10.15 | 5.17 | 4.97 |
| | May/Jun | $74 | 13.07 | 9.67 | 4.93 | 4.74 |
| | Jun/Jul | $74 | 13.57 | 10.04 | 5.12 | 4.92 |
| | Jul/Aug | $74 | 14.15 | 10.47 | 5.34 | 5.13 |
| | Aug/Sep | $74 | 16.72 | 12.37 | 6.31 | 6.06 |
| | Sep/Oct | $74 | 22.10 | 16.72 | 8.34 | 8.01 |
| | Oct/Nov | $74 | 23.25 | 17.21 | 8.77 | 8.43 |
| | Nov/Dec | $74 | 26.95 | 19.94 | 10.17 | 9.77 |
| BBR | Jan/Feb | $74 | 21.54 | 15.94 | 8.13 | 7.81 |
| | Feb/Mar | $74 | 20.55 | 15.21 | 7.76 | 7.45 |
| | Mar/Apr | $74 | 15.55 | 11.51 | 5.87 | 5.64 |
| | Apr/May | $74 | 16.42 | 12.15 | 6.20 | 5.95 |
| | May/Jun | $74 | 12.37 | 9.15 | 4.67 | 4.49 |
| | Jun/Jul | $74 | 13.90 | 10.29 | 5.25 | 5.04 |
| | Jul/Aug | $74 | 12.88 | 9.53 | 4.86 | 4.67 |
| | Aug/Sep | $74 | 14.85 | 10.99 | 5.60 | 5.38 |
| | Sep/Oct | $74 | 19.22 | 14.22 | 7.25 | 6.97 |
| | Oct/Nov | $74 | 25.41 | 18.80 | 9.59 | 9.21 |
| | Nov/Dec | $74 | 25.84 | 19.12 | 9.75 | 9.37 |

Note: GSL = Gudmundsen Sandhills Laboratory. BBR= Barta Brothers Ranch.

**Table 2.** Effect of Yearly Precipitation on Forage Production

| | Forage Production (pounds per acre) | |
|---|---|---|
| Variable | Parameter | Robust Standard Error |
| $k$ (scalar) | 750.36* | 427.390 |
| $\delta$ (rate) | -0.038** | 0.015 |
| $\rho$ (shape) | -0.026 | 0.291 |
| $\gamma$ (location, BBR=1) | -202.24*** | 42.494 |
| $R^2$ | 0.7135 | |

Note: Single asterisk (*) indicates significance at the 10% level. Double asterisk (**) indicates significance at the 5% level. Triple asterisk (***) indicates significance at the 1% level.

**Table 3:** Yearly Production Deviations and RI-PRF Insurance Scenario Net Returns Per Acre

| Location | Year | Deviation from Predicted Production | Forage Production* | Insurance Scenarios | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Low[1] | Low/ High[2] | High Early[3] | High Late[4] | High/Medium/Low[5] | Medium/ Low[6] |
| GSL | 2004 | 5% | 1396 | 1.04 | -6.95 | -4.95 | -4.93 | 34.86 | 24.16 |
| | 2005 | -2% | 1780 | 38.97 | 20.56 | -0.13 | 18.91 | 2.51 | 12.03 |
| | 2006 | 11% | 1383 | 28.01 | 20.73 | 12.56 | 17.55 | 25.87 | 33.35 |
| | 2007 | -3% | 1910 | -9.46 | -6.95 | 0.07 | -4.75 | 23.02 | 7.27 |
| | 2008 | 11% | 1897 | 35.33 | 23.39 | -4.95 | -4.93 | -7.04 | 5.56 |
| | 2009 | -36% | 2000 | -0.59 | -6.95 | -4.95 | -4.93 | -7.04 | -0.02 |
| | 2010 | 12% | 2383 | 5.46 | -6.95 | -4.47 | -4.93 | -7.04 | 6.03 |
| | 2011 | 3% | 2434 | -1.19 | -6.95 | -4.95 | -4.93 | -7.04 | -0.62 |
| | 2012 | 25% | 1362 | 6.62 | 18.29 | 23.23 | 37.96 | -7.04 | 7.19 |
| | 2013 | 25% | 1980 | -1.32 | -6.95 | -4.95 | -4.93 | 14.47 | 24.87 |
| | 2014 | -18% | 1583 | -2.3 | -5.88 | -0.96 | -4.93 | -7.04 | -2.8 |
| | 2015 | 9% | 2009 | -9.46 | -6.95 | -4.95 | 3.56 | -4.46 | -8.89 |
| Average | | | 1843 | 7.59 | 2.37 | 0.05 | 3.23 | 4.5 | 9.01 |
| BBR | 2001 | -82% | 315 | -8.59 | -6.15 | -5.5 | -4.58 | 6.88 | -8.17 |
| | 2002 | -42% | 663 | 9.46 | 37.47 | 39.91 | 28.15 | -7.3 | -8.17 |
| | 2003 | -47% | 771 | 37.82 | 10.38 | -5.5 | 9.48 | -7.3 | 21.72 |
| | 2004 | 27% | 1717 | 16.9 | 28.3 | 22.56 | 23.21 | 26.08 | 21.64 |
| | 2005 | 9% | 2117 | 26.68 | 15.6 | -5.5 | -0.67 | -7.3 | 5.36 |
| | 2006 | -13% | 1150 | 43.83 | 44.71 | 29.67 | 40.11 | 17.7 | 37.63 |
| | 2007 | -7% | 1710 | -8.59 | -6.15 | 2.36 | 5.08 | 17.2 | -8.17 |
| | 2008 | 14% | 2105 | 17.8 | 16.38 | -1.55 | 2.66 | -3.72 | -4.3 |
| | 2009 | 70% | 3548 | 4.61 | -4.01 | -5.5 | -4.58 | -7.3 | 2.89 |
| | 2010 | 52% | 3418 | 24.92 | 3.72 | -5.5 | -4.58 | -7.3 | 15.47 |
| | 2011 | 67% | 3057 | 9.75 | -6.07 | 4.67 | -4.58 | 9.52 | 11.19 |
| | 2012 | 128% | 2727 | 26.77 | 21.97 | 21.89 | 36.86 | -7.3 | 17.65 |
| | 2013 | 114% | 2934 | 13.73 | -3.64 | -1.34 | -4.58 | 40.39 | 40.67 |
| | 2014 | 23% | 2176 | 22.98 | 15.15 | 8.17 | -4.58 | -7.3 | 2.11 |
| | 2015 | 80% | 2674 | -8.59 | -6.15 | -5.5 | -4.58 | 2.61 | -0.48 |
| Average | | | 2072 | 15.3 | 10.78 | 6.22 | 7.52 | 4.37 | 9.8 |

Note: GSL = Gudmundsen Sandhills Laboratory. BBR= Barta Brothers Ranch. Avg is average. Each insurance scenario uses a 90% Coverage Level, 100% Productivity Factor, and an interval allocation of 50%. * Pounds per acre. [1] represents Jan/Feb and Nov/Dec intervals. [2] represents Jan/Feb and May/Jun. [3] represents Apr/May and Jun/Jul. [4] represents May/Jun and Jul/Aug. [5] represents Aug/Sep and Oct/Nov. [6] represents Sep/Oct and Nov/Dec.

**Table 4: Forage Production Expected Net Income from No Insurance and RI-PRF Insurance Scenarios**

| | | | Insurance Scenarios | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location | Year | No Insurance | Low[1] | Low/ High[2] | High Early[3] | High Late[4] | High/Medium/Low[5] | Medium/ Low[6] |
| GSL | | | | | | | | |
| | Average | 73.26 | 80.86 | 75.63 | 73.31 | 76.49 | 77.77 | 82.27 |
| | Variance | 205.78 | 368.83 | 208.83 | 122.92 | 180.21 | 241.53 | 190.83 |
| BBR | | | | | | | | |
| | Average | 82.37 | 97.66 | 93.13 | 88.59 | 89.89 | 86.74 | 92.17 |
| | Variance | 1623.59 | 1812.65 | 1334.61 | 1417.04 | 1370.1 | 1821.7 | 2106.47 |

Note: GSL = Gudmundsen Sandhills Laboratory. BBR= Barta Brothers Ranch. Each insurance scenario uses a 90% Coverage Level, 100% Productivity Factor, and an interval allocation of 50%. [1] represents Jan/Feb and Nov/Dec intervals. [2] represents Jan/Feb and May/Jun. [3] represents Apr/May and Jun/Jul. [4] represents May/Jun and Jul/Aug. [5] represents Aug/Sep and Oct/Nov. [6] represents Sep/Oct and Nov/Dec. Yearly data is available upon request to the corresponding author.

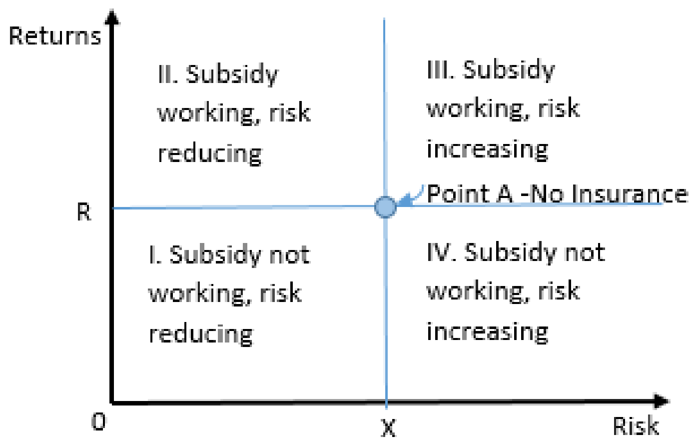
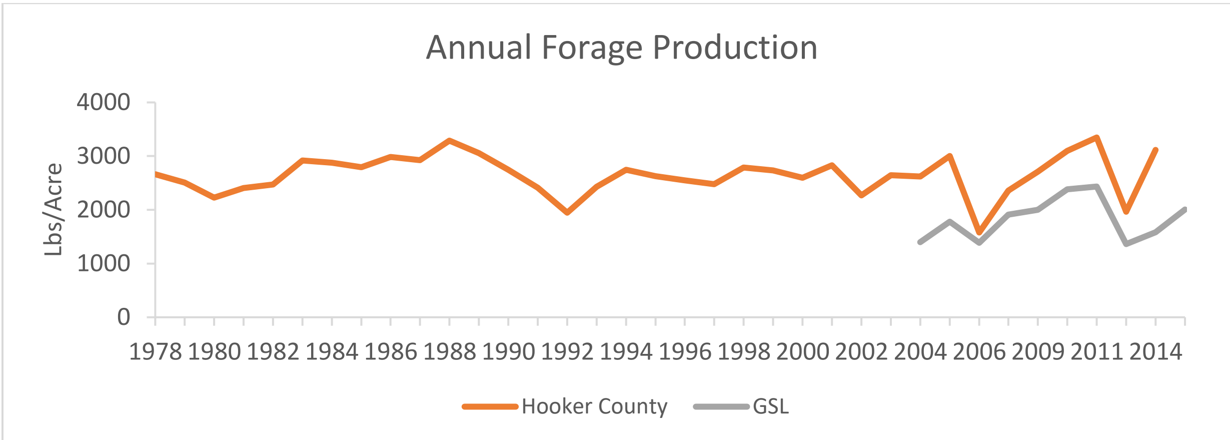



Figure 1: Outcomes from Adopting Subsidized Insurance.



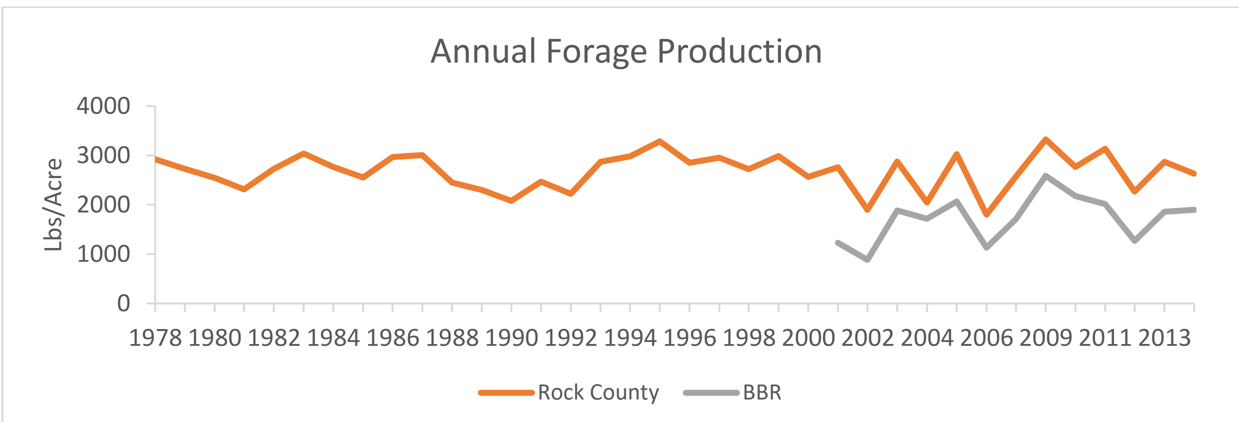




Figure 2. Comparison of Historical Forage Yield Production Between County and Farm (1978 – 2015)

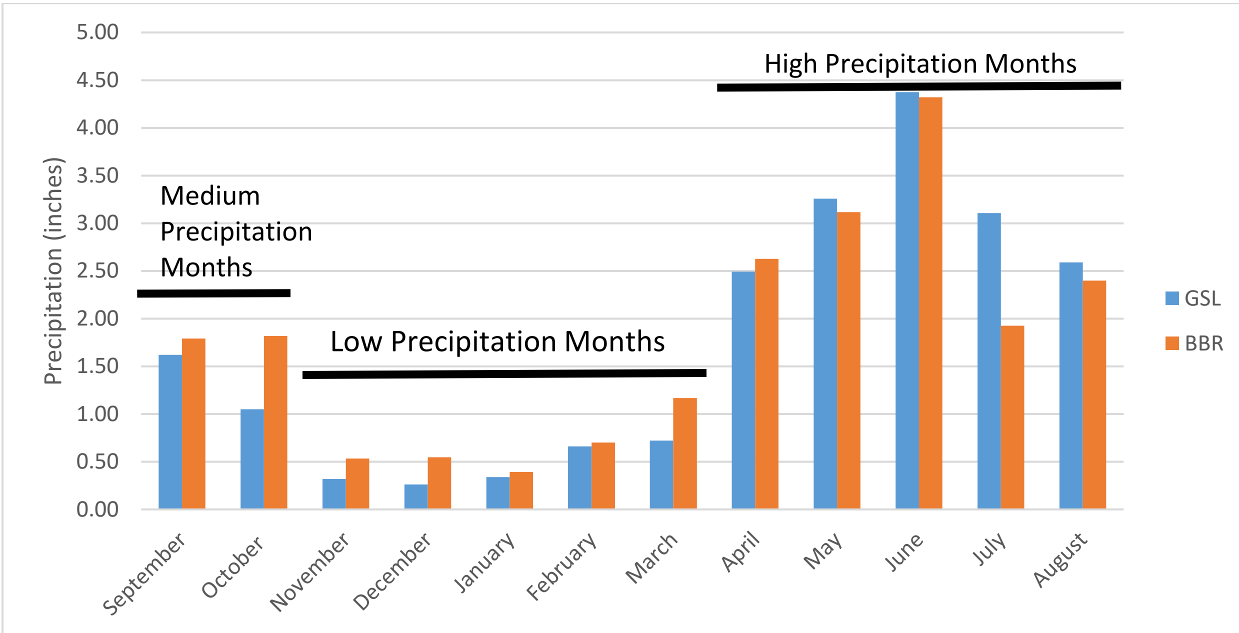



Figure 3. Average Historical Monthly Precipitation by Farm Location

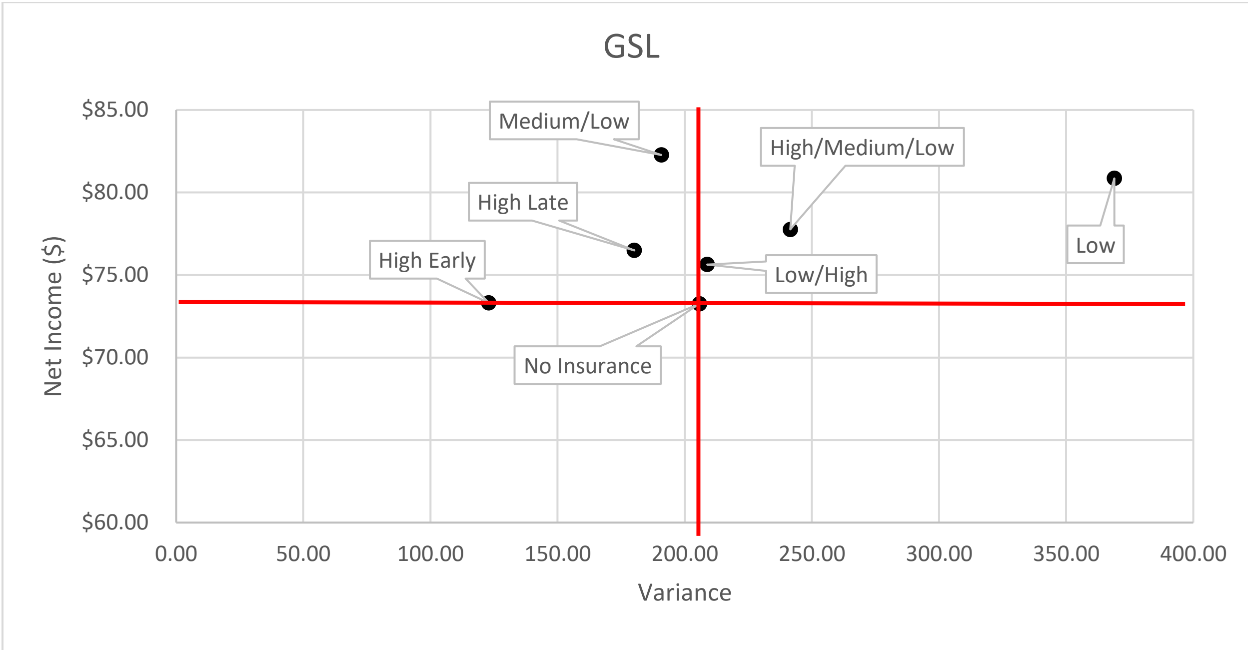



Figure 4: Gudmundsen Sandhills Laboratory Expected Returns versus Variance for Varying Insurance Scenarios

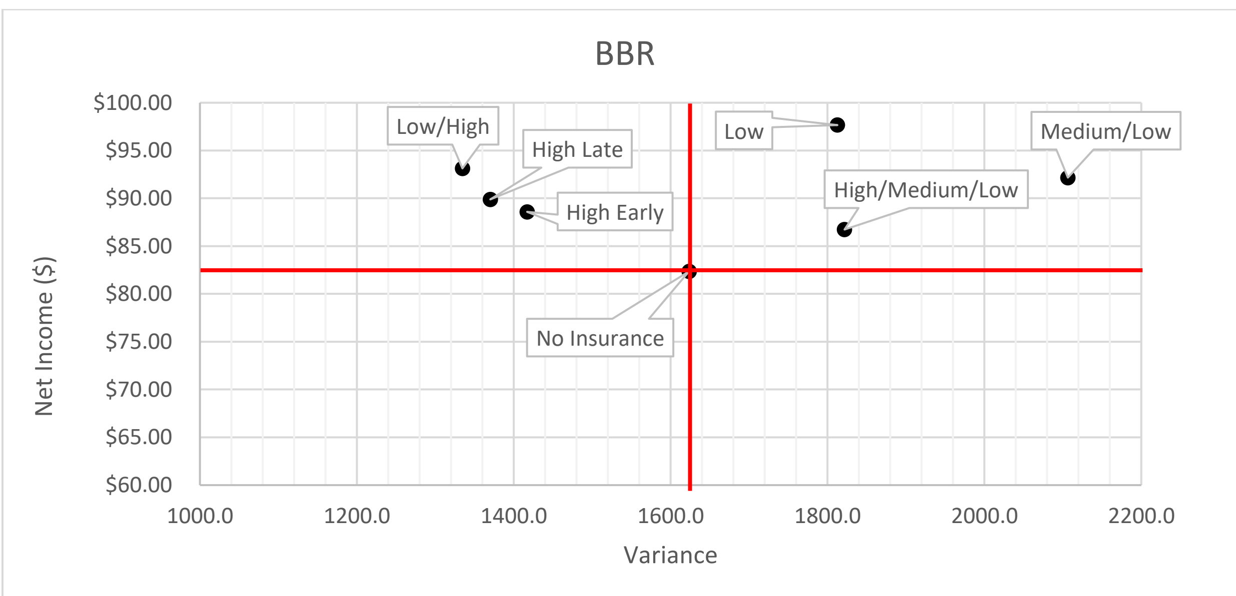



Figure 5: Barta Brothers Ranch Expected Returns versus Variance for Varying Insurance Scenarios