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Financial Outcomes from Selection of Insurance Intervals

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FINANCIAL OUTCOMES FROM SELECTION

OF INSURANCE INTERVALS

by

Shana Anderson Stewart

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of the requirements for the degree

of

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ABSTRACT

Financial Outcomes from Selection
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Utah State University, 2018

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The purpose of this paper is to demonstrate the potential value of enrolling in rainfall-index for pasture, rangeland, and forage insurance for Utah producers. A stochastic optimization model is used to identify the optimal selection of insurance intervals that will provide the maximum indemnity payments less premiums. Four Utah counties were selected for analysis. Results indicate that positive returns will occur greater than 60% of the time in all counties with the selected insurance intervals. The optimal months to insure varied in each county.

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The purpose of this paper is to demonstrate the potential value of enrolling in rainfall-index for pasture, rangeland, and forage insurance for Utah producers. A stochastic optimization model is used to identify the optimal selection of insurance intervals that will provide the maximum indemnity payments less premiums. Four Utah counties were selected for analysis. Results indicate that positive returns will occur greater than 60% of the time in all counties with the selected insurance intervals. The optimal months to insure varied in each county. In the North Cache County optimal intervals to insure are June-July and August-September. In central Utah Duchesne County optimal intervals to insure are April-May and October-November. In the East Sanpete County optimal intervals are May-June and August-September. Finally, in the West, Beaver County optimal intervals to insure are primarily March-April and July-August. Results indicate that producers in Utah would likely benefit from enrolling in the Rainfall Index for Pasture, Rangeland, and Forage insurance.

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INTRODUCTION

From the inception of the Federal Crop Insurance Program (FCIP) in the 1930's to the 2000's, demand for crop insurance has remained low (Glauber et al., 2002). In an attempt to curb disaster relief spending, Congress sought to encourage participation in the FCIP (Glauber et al., 2002). Bills were passed to reform the program in 1980, 1994, and 2000, and further Farm Bill amendments in 2008, 2014, and 2018. The Agricultural Risk Protection Act (ARPA) of 2000 established the major components of the crop insurance program that are in place today. This includes increased federal premium subsidies, and new insurance products that can be designed by private industry. Increased premium subsidies has led to more participation in insurance programs. New, innovative, insurance products have led to more options for producers who do not grow one of the major crops (corn, soybeans, wheat, and cotton).

Prior to the ARPA, producers favored other risk mitigation options and often chose to forgo crop insurance altogether (Glauber et al., 2002). Other risk mitigation options available to producers include enterprise diversification, vertical integration, production contracts, marketing contracts, hedging in futures, future options contracts, maintain financial reserves and leveraging, liquidity, leasing inputs, and hiring custom work. For a full review of other risk mitigation options, see Harwood et al. (1999). Federal disaster assistance is another potential risk mitigation tool available to producers.

Crop insurance participation rates stayed below 40% of eligible acreage until the Crop Insurance Reform Act of 1994, when rates increased to above 60%, and sometimes 70%. Participation, premium, and subsidy rates from 1981 to 2001 are described in Table I. Coverage levels were still relatively low, with less than 10% of enrolled acres in coverage levels above 65%. The passage of the ARPA in 2000 further increased participation rates, and increased coverage levels. The increases were partially in response to the much higher subsidy rates offered for higher coverage levels (Glauber et al., 2002). Research done by Just, Calvin, and Quiggin (1999) demonstrated that the decision to participate in crop insurance was usually driven by expected benefits rather than by risk aversion.

Table I. Federal crop insurance program, 1981-2001

Year	No. of Policies (1000s)	No. of Acres (millions)	Participation Rate	Total Premium ($ mil.)	Producer Premium ($ Mil.)	Subsidy Rate
1981	416.8	45	16	376.8	329.8	12%
1982	386.0	42.7	15	396.1	304.8	23%
1983	310.0	27.9	12	285.8	222.1	22%
1984	389.8	42.7	16	433.9	335.6	23%
1985	414.6	48.6	18	439.8	339.7	23%
1986	406.9	48.7	20	379.7	291.6	23%
1987	433.9	49.1	22	365.1	277.5	24%
1988	461.0	55.6	25	436.4	328.4	25%
1989	949.7	101.7	40	819.4	613.1	25%
1990	893.7	101.3	40	835.5	620.5	26%
1991	706.2	82.3	33	736.4	546.5	26%
1992	663.1	83.1	31	758.7	562	26%
1993	678.8	83.7	32	755.6	555.6	26%
1994	800.4	99.4	38	948.9	694.1	27%
1995	2,039.2	220.5	41/85	1,543.00	653.8	58%
1996	1,623.3	204.9	44/76	1,838.40	856.4	53%
1997	1,319.6	182.2	43/67	1,773.80	872.3	51%
1998	1,242.4	181.8	46/69	1,874.20	928.4	50%
1999	1,288.7	196.9	53/73	2,309.70	918.4	60%
2000	1,322.8	206.3	59/76	2,538.70	1,191.40	53%
2001	1,297.5	211.6	63/78	2,959.30	1,189.10	60%

Source: Glauber et al. (2002)

The benefit provided by federal insurance subsidies has increasingly bolstered crop insurance participation numbers. Crop insurance participation by the major crop producers now above 80%, and producers are currently relying on crop insurance as their primary safety net (USDA, 2015-2018). For producers who do not produce one of the major crops (corn, wheat, soybeans, and cotton), participation continues to remain relatively low (Shields, 2015). This is in part due to the lack of insurance options for non-major crop production.

One recent innovative insurance product made possible by ARPA and managed within the FCIP is the rainfall-index for pasture, rangeland, and forage (RI-PRF) program. This insurance option allows for the inclusion of more varied types of agricultural production. RI-PRF was introduced, along with a vegetation index version, as pilot programs in 2007. Vegetation index was replaced by rainfall index and was made available for all 48 contiguous states by 2016. Enrollment in RI-PRF has steadily increased from 52 million acres in 2016, to 75 million in 2017, and again increased to 98 million in 2018. However, this still only accounts for 15% of the 650 million acres of pasture and rangelands in the United States. By contrast, the participation rate for corn was at 87%, and for cotton was at 93% in 2012 (Shields, 2015).

The geographic distribution of crop insurance participation follows the geographic distribution of crop production. Figure 1 illustrates this geographic distribution for 2012, before the introduction of RI-PRF in most states. States that do not produce one of the four major crops also do not have high FCIP participation rates, resulting in an unequal distribution of federal subsidy dollars. Lusk (2017) demonstrated this disparity by modeling the welfare benefits that would occur if premium subsidies were removed from the FCIP. Midwestern and Southern states, states which grow cotton, wheat, corn, and soybeans, generally had a reduction in welfare from the loss of premium subsidies. Western and Northeastern states had welfare gains from the removal of subsidies, under the assumption that the tax dollars spent are returned to the taxpayers.

Utah, like other states in the Intermountain West, is dominated by livestock production and has generally not benefited from insurance programs or federal premium subsidy dollars. According to the USDA National Agricultural Statistics Service (2017), the total production value of wheat and corn in Utah, the only major crops produced in Utah, was at $41.8 million. The value of cattle and hay production, however, was $747.4 million in the same year.

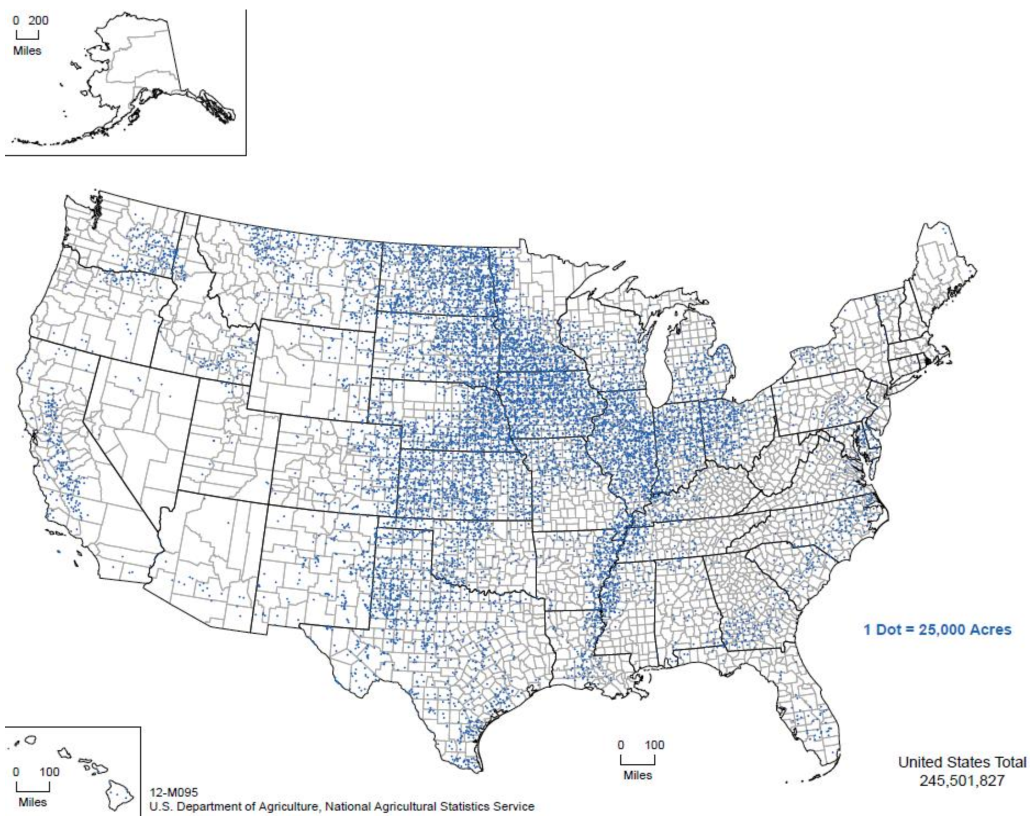

Figure 1. Acres enrolled in crop insurance, 2012

Source: Congressional Research Service, *Federal Crop Insurance: Background 2015*

The introduction of RI-PRF as an insurance option is beginning to change the insurance program disparity between states based on type of agriculture produced. In 2014 Utah had a total of 183 thousand acres insured under any insurance program. By 2018, that number increased to 5.19 million acres, only 81,000 of which was not RI-PRF. Figure 2 illustrates the limited number of acres in Utah that were insured prior to the introduction of RI-PRF as an insurance option. The dramatic increase in acres insured is a result of the growing awareness of this insurance option that is now available to livestock producers.

This paper will demonstrate the potential financial benefit of participation in RI-PRF for producers in Utah. More participation in federal insurance programs would lead to a more equitable distribution of federal subsidy dollars to rural communities in Western states.

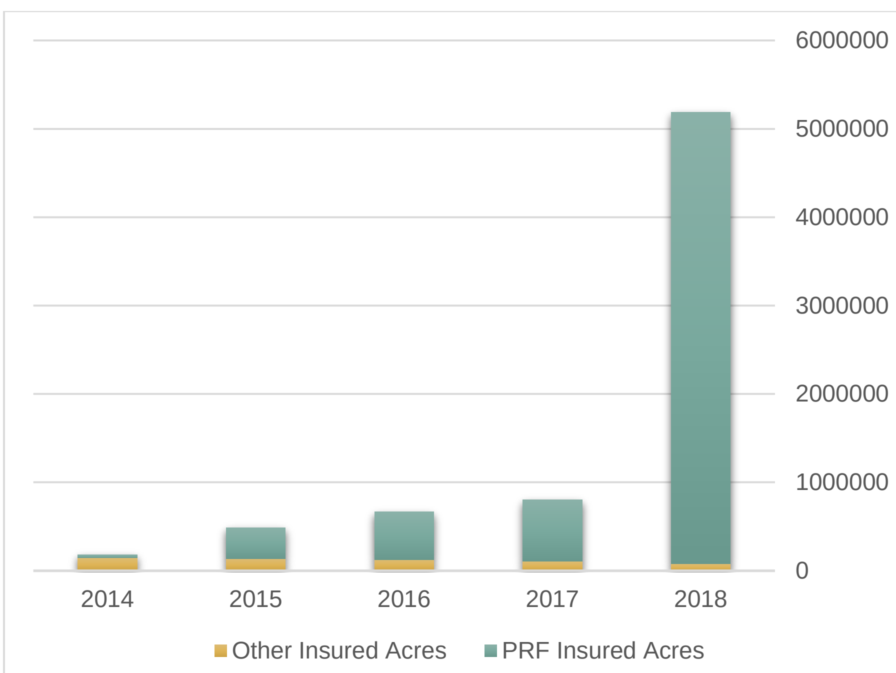

Figure 2. Acres insured in Utah, 2014 - 2018

Source: U.S. Department of Agriculture, Risk Management Agency *Summary of Business Report (2014-2018)*

This paper will focus on the selection of insurance intervals that will maximize returns while appropriately managing risk. Previous research has done similar analysis for South Dakota (Diersen et al., 2015), Oklahoma (Maples et al., 2016), and Nebraska (Carlson et al., 2017). Utah has its own unique climate and growing seasons that require local analysis; as Vedenov and Barnett (2004) explained, for index insurance to work, analysis must be highly localized. Four counties in Utah will be analyzed. Counties were selected for higher levels of animal agricultural production and geographic distribution in the North, East, West, and Central regions of the state. The counties selected are Cache (North), Duchesne (East), Beaver (West), and Sanpete (Central). Figure 3 illustrates the locations of the four counties within the state of Utah.

Producers and insurance providers can gain a clearer understanding of the insurance interval risks in the varied climates of the Utah high desert. The National Climate Data Center has classified Utah into seven climate divisions (Figure 4). Six of the seven climate divisions can be characterized as steppe or semi-arid under the Köppen-Geiger climate classification system. Steppe or semi-arid climates are characterized by hot, dry summers, cold winters, and average annual precipitation between 5 to 15 inches. Most precipitation occurs during the winter months, with summer precipitation mostly a result of convective thunderstorms near mountainous areas (Gillies and Ramsey, 2009).

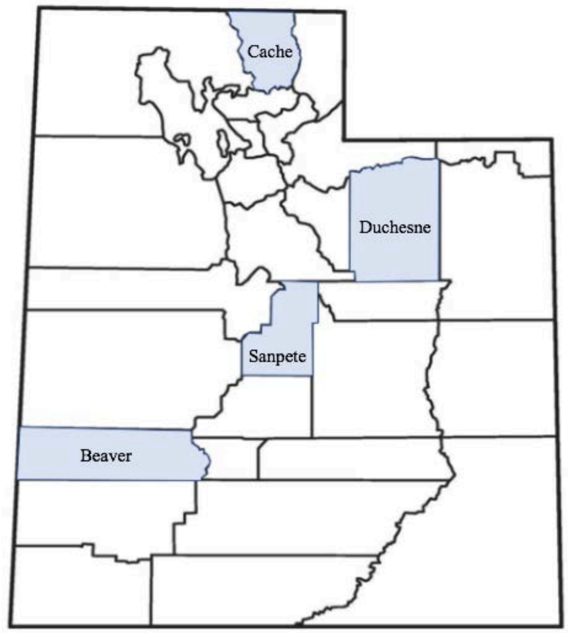

Figure 3. Location of four selected counties in Utah

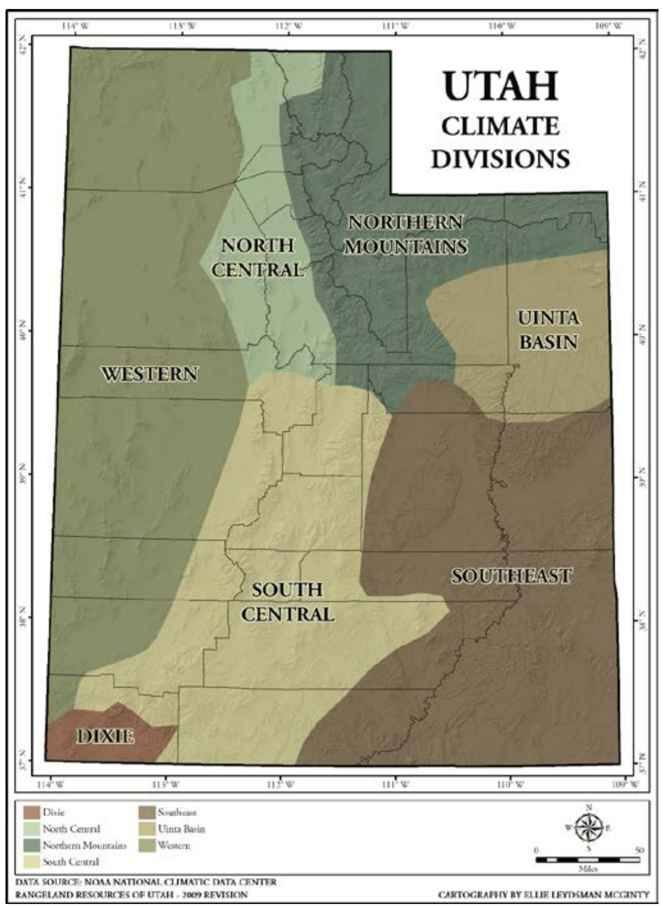

Figure 4. The seven Utah climate zones

Source: Gillies and Ramsey, 2009

Cache County is the only one of the four counties under review that is not completely characterized as steppe or semi-arid. Likewise, Cache County has a higher annual average precipitation than the other three counties at 18 inches per year. The other three counties have an annual precipitation of 12 inches or less. Summary statistics for annual precipitation in each county are listed in Table II.

Average monthly precipitation hovers around one inch, and never exceeds 2 inches of precipitation in any of the reviewed counties. Additionally, variation can be significant, for example, the month of September in Beaver, Duchesne, and Sanpete counties, will, at times, receive no precipitation, however, that same month, on other years, can receive the highest historical levels of precipitation for any given month (3.78 in Beaver and Duchesne, and 5.29 in Sanpete). Variation is highest in the late summer and early fall, likely due to the convective thunderstorm activity during that time of year.

Precipitation patterns in these Utah counties will affect expected indemnity payments under RI-PRF. The implications of a low average and high variation is that one big storm during any two-month interval could easily push total precipitation for that month above the index threshold, even while the rest of the interval is dry. This conundrum may only get worse with climate change.

Table II. County summary statistics of annual precipitation (inches)

	Beaver	Cache	Duchesne	Sanpete
Average	9.8	17.49	8.17	12.11
Standard Deviation	2.26	4.41	2.11	2.72
Min	4.88	8.48	2.36	6.63
Max	15.06	32.92	12.84	21.29

Source: NOAA National Centers for Environmental Information, *Global Summary of the Month*

The Utah climate is unique in both the very low levels of average precipitation (Utah is the second driest state in the country after Nevada), as well as the expected impacts of climate change. Climate change predictions indicate that temperatures will rise, evapotranspiration will increase, snowfall will decrease, but rainfall will increase (EPA, 2016). Average precipitation in the three of the four surveyed counties in Utah has been increasing over the last 70 years (Figure 5). Increased precipitation might result in a lower probability of receiving indemnity payments while producers are facing higher temperatures and greater evapotranspiration rates which could exceed the benefits of the extra precipitation.

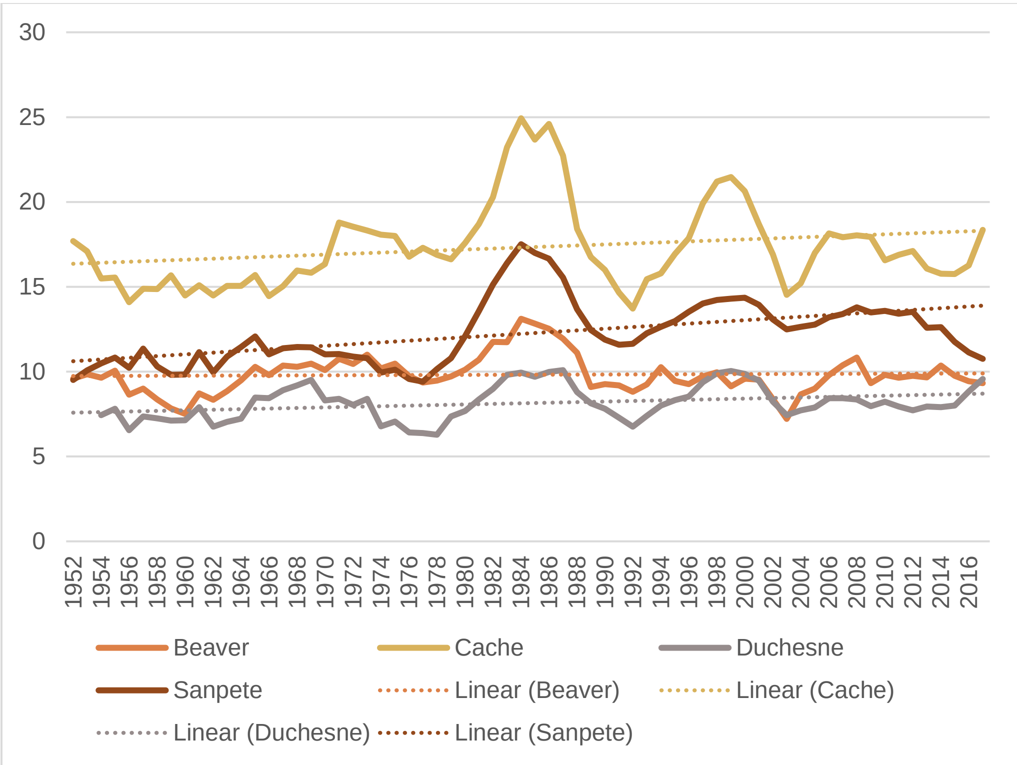

Figure 5. Annual average precipitation trends for selected counties

This paper proceeds as follows. First, a literature review covering risk in agriculture, index insurance, and rainfall-index insurance specifically, followed by a description of the RI-PRF program. The objectives of the paper are described. Then, the data, and conceptual model are introduced with an empirical analysis. Findings are presented and interpreted in the results section, with conclusions in the last section.

PREVIOUS WORK – LITERATURE REVIEW

Risk in Agriculture

There are several different types of risk in agriculture, these risks include price/market, yield/production, human/personal, institutional, and financial risk. Price/market risk can be a result of changes to output price or input cost and are subject to a wide range of global forces. Production/yield risk can be a result of weather variation, insect activity, disease, or other natural forces, but is also subject to advancing technologies. Human/personal risk is the risk of operators to death, divorce, injury, or poor health, and can also include loss due to theft or business malpractice. Institutional risk is the varying of regulations or policies that affect things such as land use, pesticide or animal drug use, as well as tax or credit policy. Financial risk relates to problems with fluctuating interest rates or equity, excess debt, or insufficient cash flow. While many of these risks are common to all business owners, some are unique to agriculture, in particular yield/production risk (Harwood et al., 1999).

Insurance is one of many options producers have to manage risk. Insurance can be considered as a form of risk pooling and works because loss does not usually occur to the combined group all at one time. This is not generally true of agriculture. Agricultural producers will often experience loss in tandem. Fluctuating commodity prices affect all growers in a uniform pattern, and yield loss frequently occurs over large geographic areas. This is one of the reasons that a private insurance market for agricultural has not independently developed. Arguments for government intervention in the crop insurance market is due to this, and other, forms of market failure in the private crop insurance markets. A complete overview of government intervention in the crop insurance market can be found in Glauber et al. (2002).

Disaster assistance offered by the federal government is another risk mitigation tool that may potentially compete with federal crop insurance. The Livestock Forage Program (LFP), for example, offers federal assistance payments following the effects of drought or wildfire on grazing lands. This disaster program could potentially compete with RI-PRF by offering relief after drought or wildfires that are partially caused by low rainfall. Carlson (2017) analyzed the effects of charity hazard as it relates to LFP and RI-PRF. Charity hazard is the opting not to enroll in insurance due to the presence of a disaster relief option. Carlson (2017) could not conclusively determine whether or not charity hazard was present. However, there was some evidence that receiving disaster assistance payments from LFP resulted in higher RI-PRF enrollment. This result may be due to a greater awareness of RI-PRF as an option after filing for LFP payments.

Moral Hazard and Adverse Selection

Before the Federal Crop Insurance Reform Act of 1994 most insurance products depended on actual farm level yield or revenue losses. These numbers can be difficult to track and verify, and often lead to the problems of adverse selection and moral hazard. Moral hazard occurs when purchasing insurance lowers the incentive for producers to manage production or incur costs that would result in higher yields, but lower indemnity payments (Glauber 2002). Adverse selection occurs when high-risk producers know they are high-risk, and thus select higher coverage levels, receive more benefits, and are under-charged, while low-risk producers are over-charged. This self-selection can cause insurance premiums to rise over time and negatively impacts the low-risk producers and contributes to the unsustainability of private insurance markets (Barret et al., 2007).

Basis Risk in Index Insurance

In 1991 Miranda revived the idea of an index insurance that was first proposed by Halcrow in 1949. Index-based insurance promised to lower administrative costs, substantially reduce the problem of adverse selection, and nearly eliminate moral hazard. The most significant problem with index-based insurance products is basis risk. Basis risk is the result of the index not actually correlating with farm level returns. High basis risk has been shown to reduce demand for index insurance (Jensen, 2018). However, basis risk can be lowered by good insurance design, better data, analyzes smaller areas, and accounts for growing season variation, and other things (Clement, 2018; Barret et al. 2007). After the 1994 Federal Crop Insurance Reform Act was passed, the first pilot programs for index insurance began. Initially, pilot programs focused on an area-yield index but have since moved to weather-based indices.

Weather Index Insurance

Turvey (2001) outlines the benefits and potential of a weather-based index insurance for managing crop yield risk. Turvey identifies weather as a transparent and easily observed index, overcoming potential adverse selection problems of average area yield index insurance plans. Turvey found that corn and soybeans are more sensitive to temperature while hay is more sensitive to rainfall. Turvey emphasized the need for payoff probabilities to be highly localized, and efforts must be made to reduce basis risk. Vedenov and Barnett (2004) analyzed weather derivatives as a risk management option for six districts producing corn, cotton, and soybeans in the United States and also conclude that weather-based index insurance contracts must be highly localized for optimal performance, and an in-depth analysis for each crop/region should be performed. One method proposed by Turvey (2001) for basis risk reduction would be to triangulate weather stations. This is the method currently used by the RMA. Norton, Boucher, and Chiu (2015) then determined that index insurance based on multiple weather station data does indeed reduce basis risk. Despite these limitations, weather-based index insurance still possesses the advantage of the ability to insure commodities that have difficult to measure yield, such as pasture and rangelands (Barnett, 2004).

Rainfall Index Insurance

Nadolnyak and Vedenov (2013) determined that long-term climate forecasts can lead to intertemporal adverse selection, when producers account for climate forecasts but insurers do not, or, if insurers do account for climate forecasts, uninsurable risk that must be borne by the producer. Ifft et al. (2014) concluded that RI-PRF insurance increases the value of pasture land by about 4%. Muller et al. (2011) suggest that while rainfall index insurance improves producer well-being, it also incentivizes less sustainable rangeland management. They conclude that the insurance strike level should be set below the long-term average as means of continuing producer benefits while improving sustainable practices.

Diesren, Gurung, and Fausti (2015) created an efficient frontier for insurance interval selection in several counties in South Dakota. They concluded that the May-June and July-August intervals are the most important for managing risk, and that enrolling in PRF-RI coverage would produce higher returns, and lower risk, compared to not enrolling in the insurance program. Allocation to the May-June and July-August intervals create a lower variance portfolio that will realize greater returns in the long run. A maximum return portfolio would require selection of the November-December and September-October intervals, but the risk is also relatively high with a standard deviation of $64, compared to the standard deviation of the minimum variance portfolio at $22.

Maples, Brorsen, and Biermacher (2016) analyzed the Rainfall Index Annual Forage Program (RIAFP) pilot in Oklahoma. Maples et al. concluded that participating in the RIAFP would also produce higher returns than not participating, similar to Diersen's conclusion that PRF-RI increases returns. In both cases the higher returns are primarily due to the high rates of premium subsidies. Unlike Diersen et al., Maples et al. looked at actual yield risk protection provided by the RIAFP. While the RIAFP is accurately correlated with precipitation, precipitation was found to not correlate with actual annual forage production. Maples et al. noted, however, that results may differ in drier regions of the West. Maples et al. also recommended that the RMA add additional insurance intervals that might correlate better with annual forage production growing and harvest periods.

Carlson et al. (2017), opposingly, did not consider regional variations, and concluded that the RMA should remove certain interval options that were found to increase a producer's risk. Carlson et al. analyzed the selection of insurance intervals using six different insurance scenarios in two locations in Nebraska. Months were categorized into low, medium, and high precipitation months, and insuring against low precipitation months was determined to increase risk. Additionally, a scenario where both low and high precipitation months are insured was the profit maximizing scenario in one location but was also high risk. While eliminating low precipitation months as insurance interval options for Nebraska might be a prudent option, other regions in the United States will likely have different outcomes.

RI-PRF PROGRAM

Rainfall Index for Pasture Rangeland and Forage (RI-PRF) is intended to insure producers of perennial forage land against a single peril, precipitation. While the name of the insurance program includes the term “rainfall,” it actually refers to all forms of precipitation. RI-PRF is not intended to insure against drought, only a comparative decrease in the level of precipitation. Precipitation is measured by the National Oceanic and Atmospheric Administration Climate Prediction Center (NOAA CPC) which uses a grid system to determine precipitation within a particular area. The grid is 0.25 degrees in latitude by 0.25 degrees longitude, approximately 17 by 17 miles at the equator. An expected grid index is calculated for each grid and index interval using long-term, historical, gridded precipitation data that is interpolated and cannot be traced back to a single reporting station (USDA-RMA). Each producer must determine which grid their acreage is located in. Producers must also select a coverage level, productivity factor, and index intervals.

Coverage levels are chosen from 70%, 75%, 80%, 85%, or 90%. Coverage level also determines the federal subsidy rate. The rate is 59% of the premium for the 70% and 75% levels, 55% for the 80% and 85% levels, and 51% for the 90% level. Productivity factor allows producers to adjust their particular forage value in 1% increments from 60% to 150% of country base value. There are eleven two-month index insurance intervals in 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. Producers must insure at least two intervals, and intervals cannot overlap, resulting in a maximum of six intervals that can be selected. 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%.

Indemnities are paid if the precipitation for the selected interval or intervals are less than the historical average at the selected coverage level. The amount of the indemnity is determined by the level of deviation from the historical mean, the coverage level, and the policy protection per unit.

$$Indemnity = Payment\ calculation\ factor \times Policy\ protection\ per\ unit \quad (1)$$

The payment calculation factor calculates the difference between the historical mean at the predetermined coverage level, or the trigger grid index and the final grid index. The trigger grid index is equal to the coverage level multiplied by the expected grid index. The expected grid index is the NOAA CPC interpolated historical gridded precipitation or successor data and expressed as a percentage with mean equal to 100. The final grid index is the NOAA CPC interpolated gridded current year precipitation data.

$$Payment\ calculation\ factor = \frac{Trigger\ grid\ index - Final\ grid\ index}{Trigger\ index} > 0 \quad (2)$$

Policy protection per unit is determined by the number of insured acres, the producer share, and the dollar amount of protection.

$$Policy\ protection\ per\ unit = Insured\ acres \times Producer\ share \times \$\ amount\ of\ porection \quad (3)$$

Dollar amount of protection is the country base value multiplied by the productivity factor and coverage level.

$$\$\ amount\ of\ protection = County\ base\ value \times Productivity\ factor \times Coverage\ level \tag{4}$$

OBJECTIVES

The objective of this paper is to demonstrate the potential value of enrolling in RI-PRF for producers in Utah. This paper will assist extension agents and producers in better understanding the risks and risk mitigation options available in one of the driest regions of the United States.

DATA

Statistical precipitation data for the four counties was gathered from NOAA Climate Data Online. Averages were compiled from two to four weather stations near the grid chosen for each county from 1950 to 2017. Cache County had the highest levels of precipitation followed by Sanpete County. Beaver and Duchesne Counties had very similar levels of precipitation, and similar precipitation patterns. All counties have had a steep decline in precipitation during the summer months of June and July, while more precipitation has generally occurred during the spring months of March and April. Periods of greatest variation have occurred during the months of September and October. Summary statistics are reported in Table III, with a color scale for ease of identifying highs and lows.

Data used for the optimization model were gathered from the USDA Risk Management Agency Decision Support Tool. Historical rainfall indices, and premium rates, are variable for each county. Premium rates per $100 for all intervals and counties are reported in Table IV. Highest rates for Beaver county are the during the October-November, September-October, and May-June intervals. Lowest rates for Beaver County are during the March-April, and February-March intervals. Highest rates for Cache County are during the July-August, and August-September intervals. Lowest rates for Cache County are during the March-April, and April-May intervals. Highest rates for Duchesne County are during the October-November, and November-December intervals. Lowest rates for Duchesne County are during the July-August, and February-March intervals. The highest rate for Sanpete County is during the May-June interval. The lowest rate for Sanpete County is during the March-April interval.

Table III. Average monthly precipitation summary statistics

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Beaver County												
Mean	0.68	0.76	1.06	0.96	0.83	0.47	0.84	1.00	0.84	0.95	0.68	0.72
St Dev	0.48	0.51	0.60	0.54	0.60	0.46	0.60	0.74	0.83	0.79	0.44	0.57
Max	2.00	2.06	3.10	2.43	2.62	1.89	2.37	3.61	3.78	3.70	1.81	2.70
Min	0.08	0.00	0.01	0.06	0.00	0.00	0.00	0.02	0.00	0.00	0.03	0.00
Cache County												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	1.64	1.46	1.75	1.96	2.00	1.30	0.59	0.84	1.29	1.57	1.51	1.55
St Dev	1.12	0.93	0.89	0.99	1.15	1.00	0.59	0.93	1.18	1.07	0.95	1.00
Max	5.20	5.38	4.14	5.38	5.47	4.47	2.47	4.74	5.16	4.62	4.93	5.19
Min	0.08	0.08	0.08	0.38	0.06	0.02	0.00	0.00	0.02	0.00	0.03	0.08
Duchesne County												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.70	0.71	1.06	0.91	0.80	0.53	0.84	1.05	0.93	1.12	0.65	0.81
St Dev	0.45	0.46	0.72	0.56	0.67	0.48	0.62	0.86	0.98	0.97	0.45	0.65
Max	2.00	2.06	3.10	2.43	2.62	1.89	2.37	3.61	3.78	3.70	1.81	2.70
Min	0.08	0.00	0.01	0.06	0.00	0.00	0.00	0.02	0.00	0.00	0.03	0.00
Sanpete County												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	1.04	1.04	1.15	1.20	1.17	0.70	0.73	0.87	1.11	1.06	0.99	1.13
St Dev	0.68	0.73	0.64	0.66	0.80	0.62	0.48	0.48	0.92	0.76	0.62	0.82
Max	2.86	3.74	2.98	3.37	3.53	2.77	2.15	2.24	5.29	3.66	3.03	4.97
Min	0.11	0.09	0.02	0.10	0.06	0.00	0.00	0.05	0.00	0.00	0.02	0.04

Source: NOAA National Centers for Environmental Information, *Global Summary of the Month*

Table IV. Insurance premiums for selected counties

	Beaver	Cache	Duchesne	Sanpete
County Base Value	7.4	7.4	3.6	5.6
Dollar Amount of Protection	6.66	6.66	3.24	5.04
Interval	Premium Rate Per $100			
Jan-Feb	18.56	17.58	24.30	20.77
Feb-Mar	15.75	17.94	18.93	16.99
Mar-Apr	14.72	13.97	19.35	13.65
Apr-May	18.93	14.32	22.79	17.48
May-Jun	24.37	18.13	24.97	22.34
Jun-Jul	22.26	22.87	22.87	20.12
Jul-Aug	17.00	26.27	18.42	16.57
Aug-Sep	23.70	25.75	20.05	20.27
Sep-Oct	24.39	21.27	23.24	20.38
Oct-Nov	25.25	17.98	25.99	19.53
Nov-Dec	21.24	20.08	25.46	18.67

METHODS

A stochastic optimization model was developed using Palisade's @Risk software. Optimization refers to the optimal allocation of resources under a set of constraints to achieve the best desired outcome. Mathematical programming is the mathematical approach to this problem and is frequently used in a variety of decision making applications. In this paper, mathematical programming is used to facilitate the decision making associated with selecting insurance intervals to maximize returns. Therefore, the desired outcome, or objective, is to maximize the insurance indemnity returns, less premiums paid. This is termed the objective function of the mathematical programming model. The formula for the objective function used in this paper is listed in equations (1) through (4).

The objective function is a function of coverage level, insured acres, producer share, productivity factor, county base value, trigger grid index, premium rates, and final grid index. All variables are deterministic with the exception of the final grid index for simplicity. The coverage level, insured acres, producer share, and productivity factor are constant for all counties. The coverage level is 90 percent, the acres insured is 1000 acres, the producer share is 100 percent, and there is a 100 percent productivity factor. The county base value is determined by county. The trigger grid index is dependent on coverage level selected, 90 percent for this model. Premium rates varied by each county and each interval. The final grid index is stochastic and is determined by historical averages.

Stochastic optimization uses Monte Carlo simulation to incorporate risk into the optimization model. A Monte Carlo simulation allows problems that might otherwise be deterministic to become stochastic through sampling hundreds or thousands of random draws from a probability distribution. Probability distributions can come in many different forms and are either univariate or multivariate. The probability distributions used in this model were determined using the historical weather averages available through RMA. The batch fit function in @Risk was used to create a distribution for each insurance interval, allowing the data to determine a multivariate distribution with the best distribution fit for each insurance interval. This process was completed separately for each county. The final grid index, a component of equation (2), becomes a stochastic variable in the model and was simulated for 1000 iterations for each county. This simulates the likelihood of precipitation that can occur in each region and for each two-month insurance interval. Allowing us to better understand the range of possible outcomes.

The resource allocation occurring in this model is the percent allocation given to what insurance interval. This is the variable cells of the model, or the solution that the optimization model will determine. The percent allocation is subject to constraints, as are all resources. The first constraint is that the percent allocated to each insurance interval must equal 100 percent. The second constraint is that at least two intervals must be selected, this constraint is imposed by allowing no more than a 60 percent allocation to any one insurance interval. The third constraint is that no two intervals in a row can be selected.

RESULTS

The results for the optimal selection of insurance intervals are listed in Table 5. Beaver County was the only county that did not have a 60/40 split in the allocation between insurance intervals. There does not appear to be any overarching pattern to the results between counties. This is likely due to the different premium rates that have already been adjusted for precipitation variation and patterns. The optimal allocation for Beaver County was 60 percent in the March-April interval, 38 percent in the July-August interval, and 1 percent in both the September-October and November-December intervals.

Table V. Optimization results, percent allocation

Interval	Beaver	Cache	Duchesne	Sanpete
Jan-Feb				
Feb-Mar				
Mar-Apr	0.6			
Apr-May			0.6	
May-Jun				0.4
Jun-Jul		0.6		
Jul-Aug	0.38			
Aug-Sep		0.4		0.6
Sep-Oct	0.01			
Oct-Nov			0.4	
Nov-Dec	0.01			

The summary statistics are listed in Table 6. Beaver County was also unique with a much higher mean, standard deviation, and maximum than the other three counties. The mean for Beaver County was 3,954 dollars. This amount is the indemnity payment above premium paid for 1000 acreage of coverage. The next highest in Cache County at $835.

The standard deviation for Beaver was $3,655, and the maximum was $20,006. Cache County again had the next highest standard deviation of $1,518, and maximum of $5,203. The minimum for Beaver County was not, however, the lowest at $-514. Both Cache County at $-784, and Sanpete County at $-521, had lower minimums. Duchesne County had the lowest average return at $374. Duchesne also had the lowest standard deviation, $706, and the lowest minimum, $-382. While a high standard deviation often indicates greater risk, in these scenarios the maximum risk can only reach the amount of premium dollars paid. Therefore, a high standard deviation is not necessarily indicative of higher risk.

Table VI. Optimization results summary statistics (US dollar)

	Beaver	Cache	Duchesne	Sanpete
Mean	3,953.75	835	374.24	427.74
Standard Deviation	3,654.74	1,518.32	706.44	870.02
Min	-513.93	-783.93	-382.14	-521.04
Max	20,005.98	5,203.06	2,385.81	3,403.61

The cumulative distribution functions of the results are displayed in Figure 6. The probability distribution functions are displayed in Figures 7 through 10. The x-axis for all graphs is the dollar amount of indemnity payments. The cumulative distribution function overlays the probabilities of returns for each county. The cumulative distribution function graphically displays the probability of all possible returns. All counties have a greater than 60 percent chance of a return that is break even or better.

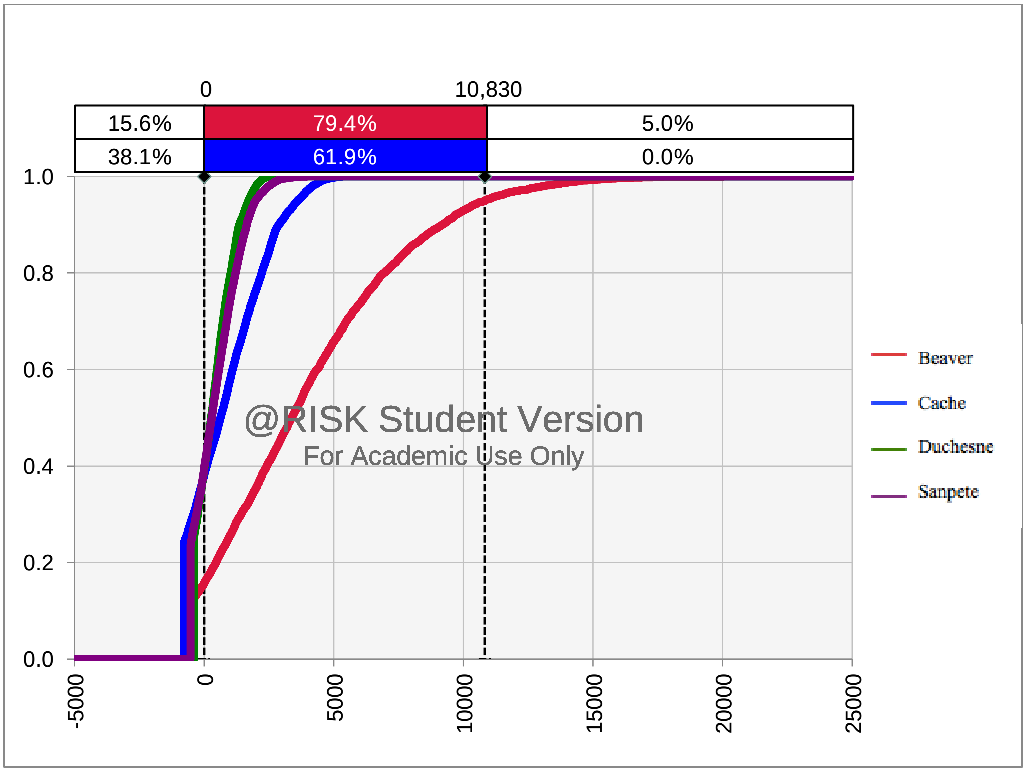

Figure 6. Cumulative distribution functions of results

Note: The cumulative distribution function displays the probability of indemnity returns above zero for the selected counties.

The probability distribution functions display the same information in a slightly different format. The height of each bar represents the probability of receiving that return amount. Beaver County has the highest probability of a positive return, with a less than 16 percent likelihood of a negative return. Duchesne and Sanpete counties are the most likely to result in negative returns at 39.4 percent and 39.9 percent respectively. While the probability of a positive return is high, there is still risk involved and producers should exercise caution when making their selections.

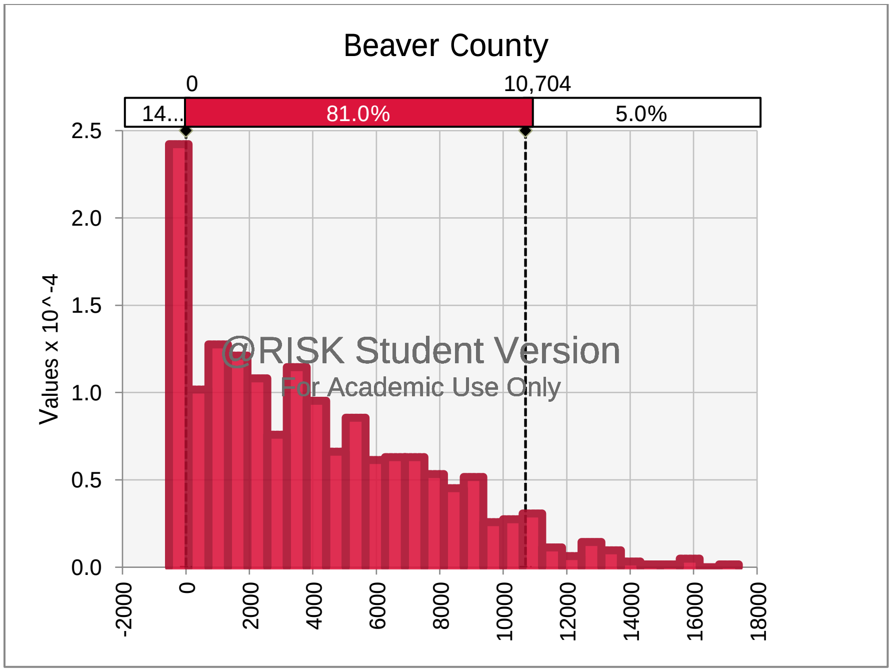

Figure 7. Probability distribution function, Beaver County

Note: The probability distribution function displays the probability of indemnity returns above zero for the selected county.

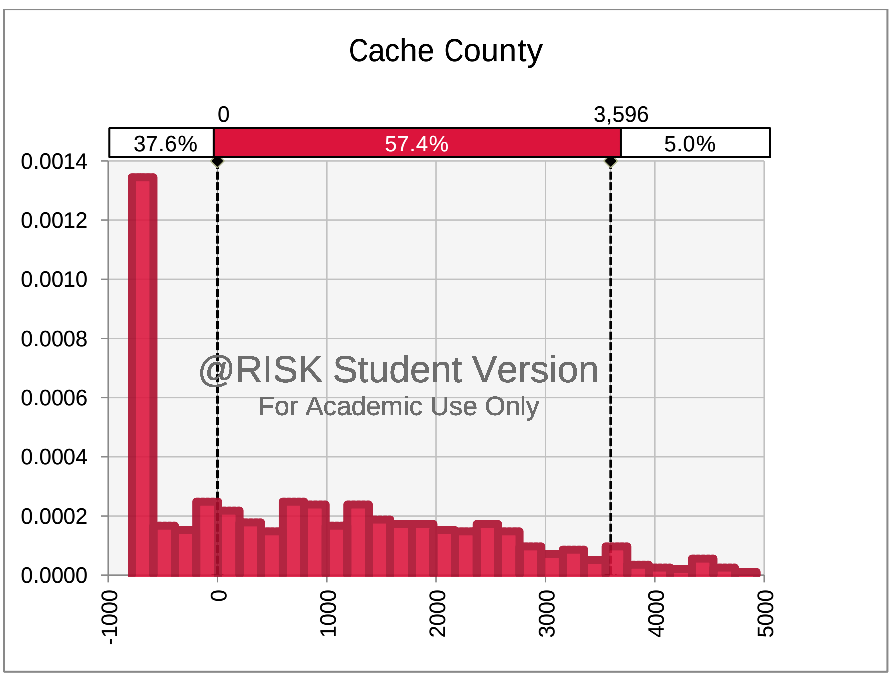

Figure 8. Probability distribution function, Cache County

Note: The probability distribution function displays the probability of indemnity returns above zero for the selected county.

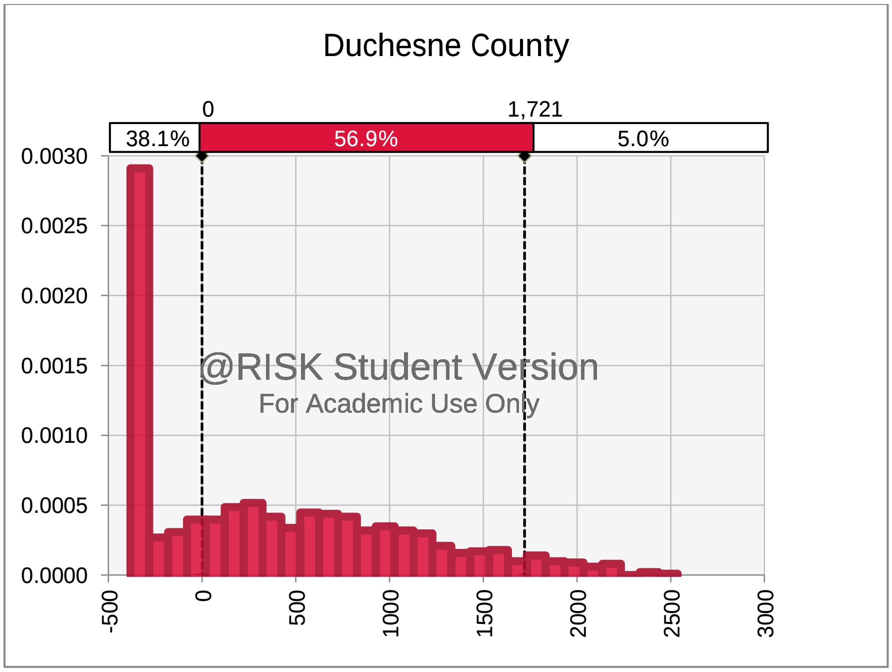

Figure 9. Probability distribution function, Duchesne County

Note: The probability distribution function displays the probability of indemnity returns above zero for the selected county.

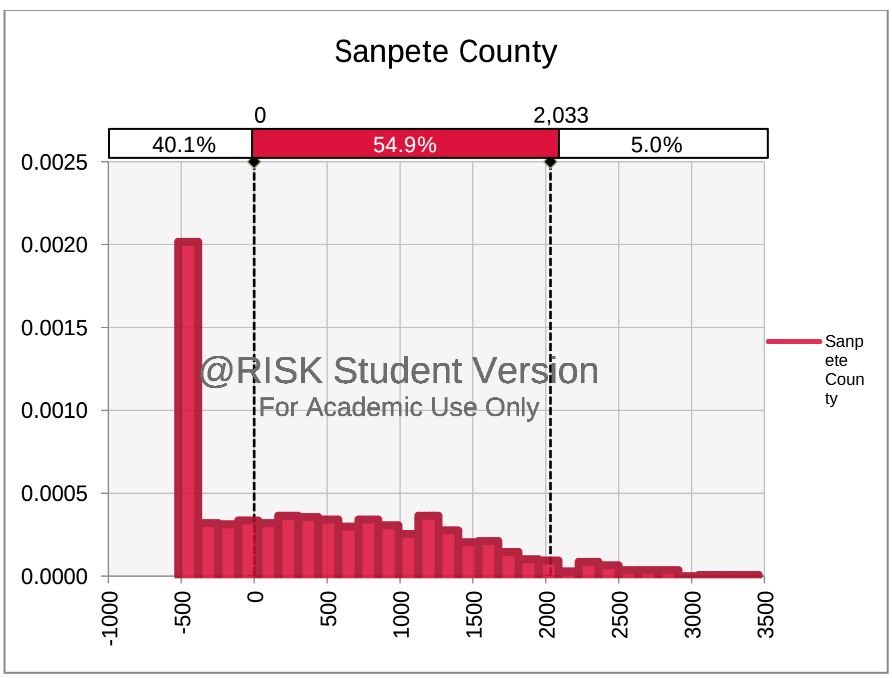

Figure 10. Probability distribution function, Sanpete County

Note: The probability distribution function displays the probability of indemnity returns above zero for the selected county.

CONCLUSION

The objective of this paper was to demonstrate the potential value in enrolling in RI-PRF insurance for Utah producers. A stochastic optimization model was used to determine the maximum returns possible when enrolling in this type of insurance. Four counties were selected for analysis. Each county had high possible returns over premiums paid with an average of $3,954 for Beaver County, $834 for Cache County, $374 for Duchesne County, and $428 for Sanpete County. All counties had a greater than 60% chance of receiving positive returns.

The implications of this research are that risk neutral producers should consider enrolling in RI-PRF insurance given the expected returns. Producers should carefully consider which insurance intervals to select when enrolling in this insurance. To maximize returns this paper recommends selecting the insurance intervals described in the results section. This paper does not consider alternative options that may be preferable to risk averse producers. Further research could pursue this question.

Further research could also incorporate more counties to assess financial returns elsewhere in the state. Additionally, further research could analyze long term climate trends and the effects this will have on the risk producers will face and if rainfall index insurance is a viable tool for mitigating climate risk long term.

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