Improving Design and Index Accuracy of PRF-RI Insurance: Integrating Forage-Based Metrics and Alternative Temporal Structures

Introduction

The Pasture, Rangeland, and Forage Rainfall Index (PRF-RI) Insurance Program serves as a critical risk management tool aimed at mitigating financial losses for producers of pasture, rangeland, and forage crops resulting from insufficient precipitation. Administered by the Risk Management Agency (RMA), the program provides coverage across the 48 contiguous states and relies on gridded precipitation data from the National Oceanic and Atmospheric Administration's Climate Prediction Center (NOAA CPC) to determine payouts (USDA Risk Management Agency 2024a). Over the years, insured acreage under PRF-RI insurance has expanded significantly, increasing from 98.93 million acres in 2018 to 297.20 million acres in 2023. Similarly, total premiums for this insurance have risen substantially, growing from $557.28 million in 2018 to $1.78 billion in 2023, while indemnity payouts have increased from $564.68 million to $1.56 billion over the same period (USDA Risk Management Agency 2024b).

Unlike yield-based policies, PRF-RI triggers indemnity payments based on deviations in observed precipitation relative to long-term historical norms, not on individual production losses (Westerhold et al. 2018). While this index-based structure allows for administrative efficiency and scalability, it introduces a fundamental tradeoff: increased basis risk. Basis risk arises when insurance payouts do not align with actual losses experienced by producers, reducing both the financial protection offered by the policy and its effectiveness as a risk management tool.

Through the years, research on PRF-RI has primarily focused on two key aspects: insurance design (Cho and Brorsen 2021; Westerhold et al. 2018) and payment accuracy (basis risk) (Yu et al. 2019; Keeler & Saitone 2020; Smith & Watts 2009; Westerhold et al. 2018). High basis risk undermines producer confidence and can discourage participation. Recent studies have found that PRF-RI's reliance

on rainfall alone may not sufficiently reflect forage production dynamics. In particular, factors such as temperature, soil conditions, and plant phenology also drive forage variability but are not incorporated into current payout triggers (Smith and Watts 2009; Yu et al. 2019). These limitations have led to calls for more refined indices that better align with actual production outcomes.

Given these limitations, this study aims to develop an improved index structure that integrates additional climate variables, specifically temperature, alongside precipitation to more accurately capture forage production risk. While temperature and soil moisture have been shown to influence forage growth (Dahl 1963; Sims and Singh 1978), they have not been formally incorporated into PRF-RI's design. This project addresses that gap by proposing a revised index that includes both precipitation and temperature metrics. Additionally, this study evaluates structural aspects of the PRF-RI program, including interval timing and spatial resolution. It tests whether changing the interval length from two months to one, or shifting from calendar-based to forage-aligned growing seasons, improves the program's responsiveness to production loss. The analysis also explores the implications of modifying the resolution of the insurance grid, assessing whether smaller units enhance accuracy. Together, these proposed changes represent a comprehensive re-evaluation of PRF-RI's design with the potential to improve both actuarial soundness and producer satisfaction.

Program Overview and Relevant Literature

PRF-RI is an index-based insurance program, meaning indemnities are determined by deviations in observed precipitation levels relative to an established index, rather than individual production losses. Each insured area is assigned to a 17 × 17-mile grid, with precipitation levels measured across 11 two-month index intervals[1]. Policyholders must select at least two non-overlapping intervals, ensuring coverage is spread across critical growing periods. Indemnities are triggered when the final grid index,

[1] Intervals include January-February, February-March, March-April, April-May, May-June, June-July, July-August, August-September, September-October, October-November, and November-December.

representing actual precipitation recorded during a selected interval, falls below the trigger grid index, which is calculated using long-term historical precipitation averages (from 1948 to two years prior to the crop year).

Producers can also choose between two insurance practices: haying or grazing. This study focuses on the grazing practice, which is widely used by livestock producers. The payout amount is determined by the payment calculation factor, which accounts for the percentage shortfall in precipitation, multiplied by the policy protection per unit. The policy protection per unit is calculated based on insured acreage, producer share, and the dollar amount of protection, which is derived from the county base value, a productivity factor (ranging from 60% to 150%), and the selected coverage level (70%, 75%, 80%, 85%, or 90%) (USDA Risk Management Agency 2024c). Premiums for PRF-RI are subsidized by the federal government, with 70% and 75% coverage levels receiving a 59% subsidy, 80% and 85% levels receiving a 55% subsidy, and 90% coverage levels receiving a 51% subsidy (Goodrich 2024).

Although PRF-RI is designed to be actuarially fair and administratively efficient, it is subject to information asymmetry (Westerhold et al. 2018) and is often criticized for its high basis risk. Cho and Brorsen (2021) examined three key design aspects of PRF-RI in Oklahoma: the accuracy of the rainfall index, the reliability of county base values, and the complexity of producer decision-making. They found that PRF-RI's decision-making process is overly complex, leading to decision fatigue among producers. To simplify the program, they suggested reducing the number of choices, focusing on critical insurance intervals and risk-reducing productivity factors. Similarly, Westerhold et al. (2018) analyzed how the selection of different two-month intervals in PRF-RI impacts risk management outcomes for forage producers in Nebraska and Kansas. Their study confirmed basis risk due to seasonal mismatches and suggested that insurance effectiveness could improve by limiting interval selection to key forage growth periods. Smith and Watts (2009) argued that rainfall index-based insurance generally has higher basis risk than yield-based indexes, as precipitation alone does not fully capture forage production losses. Keeler and Saitone (2020) estimated basis risk in PRF-RI in California and found that the correlation between

rainfall-based indemnity triggers and actual forage production was weak. Their study reported that basis risk ranged from 31% to 59%, significantly higher than the 26% estimated for Kansas and Nebraska by Yu et al. (2019). Yu et al. (2019) further emphasized that basis risk in PRF-RI is largely driven by non-precipitation factors rather than the insurance program's design. Overall, previous research has established that PRF-RI's insurance design can be improved, but basis risk will persist due to factors beyond the structure of the program. Basis risk is influenced not only by the design of the insurance itself but also by non-precipitation factors, such as temperature, soil conditions, and forage growth patterns, which affect the accuracy of payouts in reflecting actual production losses.

Several research studies have identified that factors other than precipitation play a crucial role in forage growth. Dahl (1963) found that while precipitation is the primary driver of forage production, temperature and soil moisture also significantly influence growth. Sims and Singh (1978) further demonstrated that temperature and precipitation together account for a substantial portion of the variability in forage production across different grassland ecosystems. These findings highlight the complex interaction between climatic variables and forage production, suggesting that a more comprehensive approach is needed to accurately assess forage availability and risk.

Methods

This study employs a comparative modeling framework to evaluate the effectiveness of an enhanced PRF-RI index designs that incorporates improved climatic information. While the current analysis focuses on a single enhanced index, the framework can be extended to test additional designs in future work. The methodological approach involves four key components: index construction, basis risk estimation, interval structure testing, and ecological stratification.

First, two indices are developed across PRF-RI grid cells. The baseline index replicates the current PRF-RI structure, using NOAA CPC gridded precipitation data to calculate two-month interval values. The proposed enhanced index incorporates both precipitation and temperature variables. To

evaluate how well these indices capture actual forage conditions, we construct a forage proxy modeled after the Rangeland Analysis Platform (RAP) framework. However, to avoid endogeneity concerns, our forage outcome variable is generated using a modified specification that excludes temperature as an input. This proxy maintains sensitivity to vegetative dynamics while remaining independent of climatic variables used in the index.

Basis risk is assessed using a probability-based framework that accounts for both false negatives and false positives, following methods used by Yu et al. (2019) and Keeler and Saitone (2020). False negatives occur when forage falls below a critical threshold but no indemnity is triggered; false positives occur when an indemnity is triggered without actual production loss. These are computed across both baseline and temperature-enhanced scenarios using the following expression:

$$Basis\ Risk = Pr\left(N_{i,g,t} < C \,\middle|\, I_{i,g,t} \geq C\right) + Pr\left(N_{i,g,t} \geq C \,\middle|\, I_{i,g,t} < C\right)$$

where $N_{i,g,t}$ is an observed biomass for interval i, grid g, year t; $I_{i,g,t}$ is the index and C is coverage level. The frequency and spatial distribution of false negatives and false positives are computed separately across the baseline and temperature-enhanced index scenarios. This dual-metric approach allows us to assess whether alternative index structures improve alignment between insurance payouts and actual forage outcomes.

Next, we test the sensitivity of index performance to the timing of insurance intervals. Historical climate and forage proxy data are reaggregated to simulate one-month (rather than two-month) index intervals, allowing us to assess whether shorter windows better capture short-duration droughts or production anomalies. Finally, the analysis is stratified by Major Land Resource Areas (MLRAs) to account for ecological variation across space. MLRAs represent coherent zones of soil, climate, vegetation, and topography. We assess whether basis risk and index performance vary systematically across these zones and whether the proposed index is more robust in certain ecological contexts.

Data

This study integrates multiple data sources to evaluate basis risk under alternative PRF-RI index structures. Specifically, we construct a forage production proxy modeled after the Rangeland Analysis Platform (RAP), which estimates Net Primary Production (NPP). To avoid endogeneity concerns associated with using temperature both in index construction and yield validation, we modify the RAP approach to exclude temperature as an input. The resulting proxy captures vegetative growth dynamics while remaining independent of the climate variables used in index design.

We complement these forage estimates with gridded precipitation and temperature data from NOAA's Climate Prediction Center (CPC). These datasets are used to construct two index types: a baseline (rainfall-only) index and an enhanced index that integrates both precipitation and temperature.

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