Forage Production Revenue Protection Price Methodology

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Introduction

The pricing methodology for the Forage Production Revenue Protection (FPRP) Crop Insurance Program uses factors applied to corn, soybean meal, and Class III milk prices to develop representative forage prices. These factors are determined for each state by relating state-level hay prices reported by the USDA National Agricultural Statistics Service (NASS) to the average closing specified futures contract prices for corn, soybean meal, and Class III milk. The same factors utilized to translate the futures prices observed during the discovery period for the commodities into a projected price for forages are also used to determine the harvest price for forages in the same insurance period. The prices discovered from the futures contracts are combined with the model weighting factor in Equation (1) which includes parameterizations of two other variables: the total tons of hay, as reported by the USDA Foreign Agricultural Service (FAS), exported in June of the commodity year through the May prior to the projected price discovery period, and the state-level total tons of forecasted hay production in the NASS August 1st Crop Production Report. This methodology also uses the USDA Agricultural Marketing Service (AMS) Hay Report data to develop type factors for each insurable type.

Sources utilized for the methodology include:

1) NASS state-level monthly hay prices[1] ("Alfalfa Hay" and "Hay, Excluding Alfalfa" in applicable states),
2) Chicago Mercantile Exchange (CME) prices for corn, soybean meal, and Class III milk[2],
3) AMS Hay Report[3] data,
4) FAS export[4] data, and
5) NASS August 1st Crop Production Report[5] state-level forecast of hay production.

Baseline Price Methodology

The NASS price series consists of monthly, state-level prices for "Alfalfa Hay" and "Hay, Excluding Alfalfa" for each state in the Forage Production Revenue Protection Crop Insurance Program. The "Alfalfa Hay"

[1] These data are released monthly in the NASS Agricultural Prices Report and can be found at quickstats.nass.usda.gov.
[2] Commodity futures contract prices are retrieved from barchart.com.
[3] The most recent AMS Hay Reports are available at www.ams.usda.gov/market-news/hay-reports and are archived at mymarketnews.ams.usda.gov.
[4] Export statistics from the FAS are published at apps.fas.usda.gov/gats.
[5] The NASS August Crop Production Report statistics can be found at quickstats.nass.usda.gov and archived reports are available in the USDA Economics, Statistics, and Market Information System at esmis.nal.usda.gov/publication/crop-production.

price series is used for the insurable alfalfa types, and the "Hay, Excluding Alfalfa" price series is utilized for the non-alfalfa insurable types. For each state in the program and each NASS hay price series, the May through October prices are utilized in this methodology as these months encompass most of the forage harvest season. The average prices for May/June, July/August, and September/October are weighted by the respective production timeline weights ($W_{i,v}$, $X_{i,v}$, and $Y_{i,v}$) published in the Forage Production Commodity Exchange Price Provisions (CEPPs) to develop an annual weighted average forage price over the harvest season. The average closing prices of the nearby corn, soybean meal, and Class III milk futures contracts are also calculated for the months of May through October. The same weighting approach is utilized to calculate weighted average annual corn, soybean meal, and Class III milk prices across the forage harvest season.

The total tons of hay exported in the months of June through May prior to the projected price discovery period are utilized along with the state-level NASS August 1st Crop Production Report's forecasted hay production relative to its five-year moving average. An annual estimation of the historical relationship of the log-transformed annual NASS weighted-average hay prices, associated with the log-transformed weighted-average corn, soybean meal, and Class III milk prices, the total tons of hay exported in the previous 12 months, and the forecasted hay production relative to its five year moving average produce the factors of $\alpha_{i,t}$, $E_{ZC,i,v}$, $E_{ZM,i,v}$, $E_{DC,i,v}$ in Equation (1). The model weighting factor $\alpha_{i,t}$, is a combination of export information, the state-level forecasted production relative to its five-year moving average, and an intercept value.

Alfalfa Type Factors

The AMS Hay Reports are utilized to establish the type factors $T_{i,v}$ in Equation (1). The Hay Report transactions are separated into "Hay", "Grain", or "Straw" categories, but only the "Hay" transactions are used in this methodology. The Hay Reports also report prices either "Per Ton" or "Per Bale". For this analysis, only the "Per Ton" data are used since bales can take many different forms and there often is insufficient detail to convert the given information to a price-per-ton basis. To exclude any freight costs, only F.O.B. prices are utilized. For the alfalfa types, transaction information is filtered to any hay reported as alfalfa or an alfalfa mix grown conventionally. The reported quality designations are then aligned with the insurable types in the Forage Production Revenue Protection Program as shown in Table 1.

Table 1: USDA AMS Alfalfa Hay Quality Designation and Nutritional Values

Hay Type	AMS Quality Designation	Relative Feed Value (RFV)	Crude Protein (CP)	Alignment with Alfalfa Insurable Type
Alfalfa	Supreme	186	>22	Alfalfa 90-100%
Alfalfa	Premium/Supreme	185	22	Alfalfa 90-100%
Alfalfa	Premium	177.5	21	Alfalfa 90-100%
Alfalfa	Good/Premium	170	20	Alfalfa 60-89%
Alfalfa	Good	160	19	Alfalfa 60-89%
Alfalfa	Fair/Good	150	18	Alfalfa 25-59%
Alfalfa	Fair	140	17	Alfalfa 25-59%
Alfalfa	Utility/Fair	130	16	Alfalfa 1-24%
Alfalfa	Utility	129	<16	Alfalfa 1-24%

The AMS daily price data for the given type of hay and quality classification are multiplied by the tons sold to arrive at a value of hay for the given day and AMS data source. This information is then combined for every day in each month and across AMS data sources (e.g. “direct” versus “auction”) to arrive at a total tonnage and value of hay sold during the month. The monthly type-specific AMS-reported hay tonnage is also multiplied to the respective NASS reported Alfalfa Hay Price for the same month to identify the NASS reported value of hay sold. To allow for the usage of the most recently available data at the time of the projected price discovery period, the 12-month period from July to June is used for states with a September 30th Sales Closing Date, and the 12-month period from August to July will be used for states with an October 31st Sales Closing Date. These 12-month periods are referred to as the Factor-Year and are depicted in Table 2.

Table 2: Months Used in Factor Year

Sales Closing Date	Months Used in Factor Year
Sep. 30	July (year) to June (year + 1)
Oct. 31	August (year) to July (year + 1)

The hay values from the Hay Reports aligned with AMS prices are then aggregated by insurable type for each Factor-Year in each region, as shown in Figure 1. The hay values from the Hay Reports aligned with NASS prices are also aggregated by insurable type for each Factor-Year in each region. Using the respective aggregate hay values for the AMS prices and the NASS prices, an annual price ratio for each insurable type relative to the NASS price is developed for each region. A 5-year moving average of the

annual Factor-Year price ratio is used as the type factor for each insurable alfalfa type.

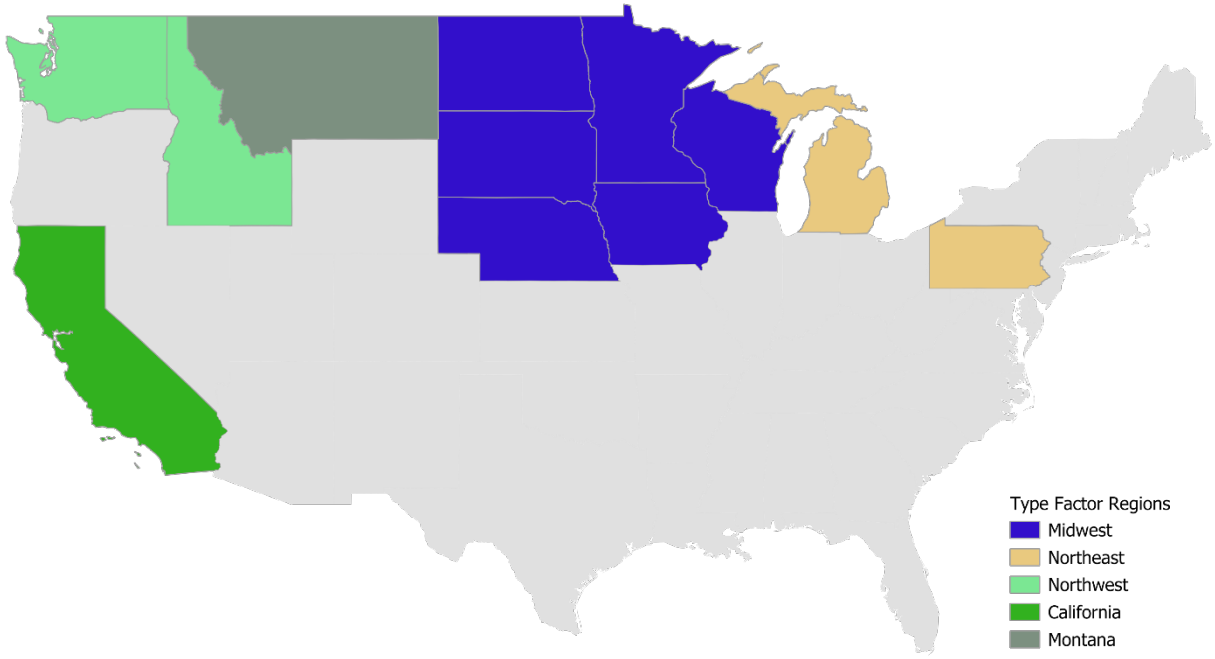

Figure 1: Type Factor Regions

Other Forage Type Factors

Type factors for Orchard and Timothy grasses are developed using the AMS Direct Idaho Hay and the AMS Direct Washington-Oregon (Columbia Basin) Hay Reports. The methodology employed for the alfalfa types is adapted to apply to Orchard and Timothy grass hay data series. Records from these reports are filtered in the same manner as done for the alfalfa types. For the Orchard and Timothy grass types, transaction information is filtered to any hay reported as "Orchard Grass" or "Timothy Grass" grown conventionally. Since there is only one insurable type for each of these grasses, there is not any differentiation by the quality designation. The AMS reported prices for these hay classifications are aggregated using the methodology employed for the alfalfa types described previously. The only difference is the NASS reported monthly Hay price series to which the AMS values are compared is the all-other hay classification that excludes alfalfa from the price being reported. The factors for the Orchardgrass and Timothy insurable types are determined on a regional basis for the Pacific Northwest which encompasses Idaho and Washington. A 5-year moving average of the annual Factor-Year price ratio is used as the regional factor for Orchard and Timothy grasses. All other insurable types are assigned a type factor of 1.00.

Price Calculations

Prior to each projected price discovery period, the factors for the Forage Production Formula Price (FPFP) will be calculated as follows:

$$FPFP_{i,v} = T_{i,v} \times \alpha_{i,t} \times F_{ZC,i,v}^{E_{ZC,i,v}} \times F_{ZM,i,v}^{E_{ZM,i,v}} \times F_{DC,i,v}^{E_{DC,i,v}} \quad (1)$$

Where

$$F_{ZC,i,v} = W_{i,v} \times P_{ZC,N} + X_{i,v} \times P_{ZC,U} + Y_{i,v} \times P_{ZC,Z} \quad (2)$$

$$F_{ZM,i,v} = W_{i,v} \times P_{ZM,N} + X_{i,v} \times P_{ZM,U} + Y_{i,v} \times P_{ZM,Z} \quad (3)$$

$$F_{DC,i,v} = W_{i,v} \times P_{DC,N} + X_{i,v} \times P_{DC,U} + Y_{i,v} \times P_{DC,Z} \quad (4)$$

$FPFP$ is the Forage Production Formula Price in dollars per ton;

i is the state;

v is the forage type;

F is the weighted average futures price for each commodity discovered during the price discovery periods;

N (July Contracts), U (September Contracts), and Z (December Contracts) are the contracts used in the price discovery periods;

W, X, and Y are the weights applied to the prices discovered in the three discovery periods;

T is the type factor;

t is the baseline model ("Hay, Alfalfa" or "Hay, Excluding Alfalfa");

P is the average daily settlement price for the projected or harvest price discovery periods for the respective harvest year's commodity futures contracts;

E denotes the exponent value applied to the settlement price;

ZC represents the corn futures contract;

ZM represents the soybean meal futures contract;

DC represents the class III milk futures contract; and

α is the model weighting factor.

The model weighting factor $\alpha_{i,t}$ is a combination of the model intercept, the export variable, and the August 1st hay production forecast from NASS by state relative to the average of the previous five years of forecasts. The August 1st Crop Production Report with the forage production forecast is typically released by August 12th. If this report is unavailable by the close of business two days prior to the beginning of the projected price discovery period, the assumed forecasted forage production will be equal to the average of the previous five years.

Price Volatility Factor

Implied volatility is utilized as a basis for determining price risk for most commodities with revenue crop insurance options. Since comparable information is not available for forages, the volatilities observed in the futures exchanges for the commodities used in the Forage Production Formula Price determination are utilized in the volatility determination. To establish the price volatility factor for forage production, a volatility factor is developed for each contract period (July, September, and December contracts). The volatility factor uses the historical volatility of the annual first differences of the export variable and the forecasted production relative to its five-year average variable, and the implied volatilities of the futures contracts. The implied volatilities for each of the corn, soybean meal, and Class III milk contracts are calculated using the USDA Risk Management Agency's published methodology[6]. The price volatility factor for each contract period is calculated through a series of matrix operations incorporating the correlations of the input variables, the baseline methodology parameters, the historical volatilities of the export and forecasted production variables, and the implied volatilities for each commodity. The formulas for these calculations are presented in the Appendix.

Using the weights in the Commodity Exchange Price Provisions, a weighted average of the three volatility factors is calculated to arrive at a final volatility factor, rounded to two decimals, bounded by a minimum of 0.01 and maximum of 0.40.

[6] https://www.rma.usda.gov/sites/default/files/topics/volatilitymethodology.pdf

Appendix: Estimating Volatility of a Price Variable based on the Functional Relationship of Historic Volatilities of Related Variables

This appendix outlines the general methodology to elicit a price volatility factor for $t = 1, \dots, T$ years of pricing data, the definitions are as follows:

Variable	Definition
$\boldsymbol{n = t - 1}$	Number of years minus one
$\boldsymbol{p_{t,d}}$	Price of dependent variable in year t
$\boldsymbol{p_{t,j}}$	Price of explanatory variable (regressor) j for $j = 1, \dots, k$ variables in year t
$\mathbf{y}^*$: $\boldsymbol{y_t^* = ln(p_{t,d})}$	$t \times 1$ vector of natural logarithm of price of dependent variable
$\mathbf{X}^* = [\mathbf{x_1} \quad \cdots \quad \mathbf{x_k}]$: $\boldsymbol{x_{t,j}^* = ln(p_{t,j})}$	$t \times k$ matrix of natural logarithm of price of for k regressors
$\mathbf{D} = \begin{bmatrix} -1 & 1 & 0 & \cdots & 0 & 0 \\ 0 & -1 & 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & -1 & 1 \end{bmatrix}$	An $n \times t$ first difference matrix operator
$\mathbf{y} = \mathbf{D}\mathbf{y}^*$: $\boldsymbol{y_t = y_t^* - y_{t-1}^*}$	First difference of natural logarithm of price of dependent variable
$\mathbf{X} = \mathbf{D}\mathbf{X}^*$: $\boldsymbol{x_{t,j} = x_{t,j}^* - x_{t-1,j}^*}$	First difference of natural logarithm of price of regressor j
$\boldsymbol{\widehat{\beta}_j}$	Regression coefficient estimate associated with regressor vector x_j based on log-log price analysis
$\widehat{\boldsymbol{\beta}}^* = \left(\mathbf{X}^{*\prime}\mathbf{X}^*\right)^{-1}\mathbf{X}^*\mathbf{y}^*$	$(k+1) \times 1$ vector of regression coefficient estimates of log-log price analysis associated with $j = 0,1, \dots, k$ regressors
$\widehat{\boldsymbol{\beta}} = \widehat{\boldsymbol{\beta}}^*_{\mathbf{1},k;\mathbf{1},\mathbf{1}}$	$k \times 1$ sub-vector of regression coefficient estimates of log-log price analysis, not including the constant coefficient ($\hat{\beta}_0$)
$\hat{\mathbf{y}}^* = \mathbf{X}^*\widehat{\boldsymbol{\beta}}^*$	$t \times 1$ vector of regression-predicted natural logarithm of price of dependent variables
$\hat{\mathbf{y}} = \mathbf{D}\hat{\mathbf{y}}^* = \mathbf{X}\widehat{\boldsymbol{\beta}}$: $\boldsymbol{\hat{y}_t = \hat{y}_t^* - \hat{y}_{t-1}^*}$	$n \times 1$ vector of first differences of regression-predicted log price of dependent variables
$\mathbf{C} = \mathbf{I} - \frac{\mathbf{1}}{\boldsymbol{n}}\mathbf{J}$	$n \times n$ centering matrix, where I is an $n \times n$ identity matrix and J is an $n \times n$ matrix of ones.
$\widehat{\boldsymbol{\Sigma}}_{\mathbf{X}} = \mathbf{X}'\mathbf{C}\mathbf{X}$	$k \times k$ sample covariance matrix of first differences of log price of independent variables
$\mathbf{R_X}$	$k \times k$ matrix of estimated correlation coefficients of first differences of log price of independent variables
$\boldsymbol{s_y^2 = \frac{1}{n}\mathbf{y}'\mathbf{C}\mathbf{y}}$	Sample variance of first difference of log price of dependent variable y
$\boldsymbol{w}$	Number of past years used to estimate average volatility
$\boldsymbol{v_{h,y} = \sqrt{w}s_y}$	Average annual historic volatility for variable y

Variable	Definition
$\boldsymbol{v_{f,x_j}}$	Implied (or forward[7]) volatility for variable x_j based on futures data options value
$\hat{\mathbf{v}}_{\boldsymbol{t}}$	$k \times 1$ vector of regressor volatility measures in year *t*
$\widehat{\boldsymbol{v}}_{\boldsymbol{t,y}}$	Estimate of implied volatility for dependent variable in year *t*

The annualized historical volatility is estimated directly for the dependent variable as $v_{h,y}$. Another means to estimate volatility is by utilizing a regression estimate of the dependent variable, in this case, monthly forage prices. Utilizing a log-log regression analysis to estimate parameters, the first difference of the predicted value of the log forage price can be utilized in the estimate of volatility:

$$\hat{v}_{h,y} = \sqrt{\frac{w}{n}\hat{\mathbf{y}}'\mathbf{C}\hat{\mathbf{y}}}$$

Then

$$\hat{v}_{h,y} = \sqrt{\frac{w}{n}\widehat{\boldsymbol{\beta}}'\mathbf{X}'\mathbf{C}\mathbf{X}\widehat{\boldsymbol{\beta}}} = \sqrt{\frac{w}{n}\widehat{\boldsymbol{\beta}}'\left[(n-1)\widehat{\boldsymbol{\Sigma}}_{\mathbf{X}}\right]\widehat{\boldsymbol{\beta}}} = \sqrt{w\widehat{\boldsymbol{\beta}}'\widehat{\boldsymbol{\Sigma}}_{\mathbf{X}}\widehat{\boldsymbol{\beta}}}$$

note that

$$\widehat{\boldsymbol{\Sigma}}_{\mathbf{X}} = \operatorname{diag}(\mathbf{s}_{\mathbf{X}})\mathbf{R}_{\mathbf{X}}\operatorname{diag}(\mathbf{s}_{\mathbf{X}}) = \operatorname{diag}\left(\frac{\hat{\mathbf{v}}_{h,\mathbf{X}}}{\sqrt{w}}\right)\mathbf{R}_{\mathbf{X}}\operatorname{diag}\left(\frac{\hat{\mathbf{v}}_{h,\mathbf{X}}}{\sqrt{w}}\right)$$

where

$$\mathbf{s}_{\mathbf{X}} = [s_{h,\mathbf{x}_1} \quad s_{h,\mathbf{x}_2} \quad \cdots \quad s_{h,\mathbf{x}_k}]' = \frac{1}{\sqrt{w}}[\hat{v}_{h,\mathbf{x}_1} \quad \hat{v}_{h,\mathbf{x}_2} \quad \cdots \quad \hat{v}_{h,\mathbf{x}_k}]'$$

so

$$\hat{v}_{h,y} = \sqrt{\widehat{\boldsymbol{\beta}}'\operatorname{diag}(\mathbf{v}_{h,\mathbf{X}})\mathbf{R}_{\mathbf{X}}\operatorname{diag}(\mathbf{v}_{h,\mathbf{X}})\widehat{\boldsymbol{\beta}}}$$

and

$$\hat{v}_{t,y} = \sqrt{\widehat{\boldsymbol{\beta}}'\operatorname{diag}(\hat{\mathbf{v}}_t)\mathbf{R}_{\mathbf{X}}\operatorname{diag}(\hat{\mathbf{v}}_t)\widehat{\boldsymbol{\beta}}}\,.$$

[7] The term "forward" volatility can be used to describe commodity price volatility since the USDA RMA price volatility methodology utilizes implied volatilities adjusted for the time period associated with harvest price discovery rather than futures contract maturity.