FFAI v3.0

Farmers First Ag Index
Technical Methodology

A statistically validated index of U.S. agricultural financial conditions
with sector-specific decomposition for grain, dairy, and livestock operations.

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VALIDATION	LOO Cross-Val r = 0.49, p < 0.000001
DATA SOURCE	16 Federal Reserve (FRED) series, Q1 2003 - present
COVERAGE	92 quarters, national scope, updated quarterly
COMPONENTS	Composite + Grain + Dairy + Livestock + Forward Outlook

EXECUTIVE SUMMARY

The Farmers First Ag Index (FFAI) measures national agricultural financial conditions using publicly available Federal Reserve economic data. The index predicts the direction and magnitude of agricultural loan delinquency, providing an early warning system for farm financial stress.

The FFAI uses just two inputs for its validated composite: soybean futures prices and the Federal Funds interest rate. This deliberately simple design resists overfitting and produces a model that has been tested against 91 quarters of actual delinquency data using leave-one-out cross-validation (r = 0.49, p < 0.000001) and expanding-window out-of-sample testing (r = 0.51, p < 0.00001). The result survives Bonferroni correction for 50 multiple comparisons at p < 0.05.

The composite index is decomposed into three sector-specific sub-indexes that show how national conditions affect different farm types differently. The critical structural feature is that corn acts as REVENUE for grain farmers but as FEED COST for dairy and livestock operations. When corn prices spike, grain farmers prosper while dairy farmers get crushed. This inverse relationship (r = -0.45) is empirically confirmed and provides genuine sector intelligence beyond what the composite alone conveys.

A forward-looking component based on the four-quarter change in the Federal Funds rate provides a 12-15 month leading indicator of farm financial stress (r = -0.52 at 4-5 quarter lead). Rising interest rates predict higher loan delinquency because farmers carry heavy debt loads and rate increases directly impact debt service costs.

INDEX ARCHITECTURE

The FFAI consists of five components organized in a hybrid architecture:

COMPOSITE   **68.0 (Favorable)**
Soy + Fed Funds regression model. Validated against national ag loan delinquency. The composite IS the validated core; sub-indexes decompose its signal into sector implications.

GRAIN   **9.8 (Stressed)**
Crop revenue (corn, soy, wheat) minus input costs (crude oil, diesel, fertilizer, farm machinery, interest). Low scores indicate crop prices are depressed relative to production costs.

DAIRY   **53.3 (Guarded)**
Milk/cheese/butter revenue minus feed costs (corn, soy) minus energy and interest. Moves INVERSELY to grain because corn is revenue for grain but cost for dairy.

LIVESTOCK   **94.6 (Strong)**
Cattle/hog revenue minus feed costs, energy, and interest. Similar cost structure to dairy but differentiated by cattle and hog producer price indexes.

OUTLOOK   **61.4 (Positive)**
Forward-looking: 4-quarter rate of change in Fed Funds. Falling rates signal improving conditions 12-15 months ahead because farmers carry heavy debt loads.

DATA SOURCES

All data sourced from the Federal Reserve Economic Data (FRED) system maintained by the Federal Reserve Bank of St. Louis. Data is publicly available, updated regularly, and spans Q1 2003 to present (92 quarterly observations). No proprietary or estimated data is used.

FRED Series ID	Description	Units	Role in FFAI
PMAIZMTUSDM	Corn (Global Price)	$/metric ton	Grain revenue, Dairy/Live cost
PSOYBUSDM	Soybeans (Global Price)	$/metric ton	Grain revenue, Dairy/Live cost
PWHEAMTUSDM	Wheat (Global Price)	$/metric ton	Grain revenue
POILWTIUSDM	WTI Crude Oil	$/barrel	Energy cost (all sectors)
WPU057303	Diesel Fuel PPI	Index	Grain input cost
WPU0652	Fertilizer PPI	Index	Grain input cost
WPU111	Farm Machinery PPI	Index	Grain input cost
WPU01610102	Raw Milk PPI	Index	Dairy revenue
PCU311513311513	Cheese Mfg PPI	Index	Dairy revenue
WPU023201	Butter PPI	Index	Dairy revenue
WPU0131	Slaughter Cattle PPI	Index	Livestock revenue
WPU013201	Slaughter Hogs PPI	Index	Livestock revenue
FEDFUNDS	Federal Funds Rate	Percent	Interest cost + Outlook
CPIAUCSL	Consumer Price Index	Index	Context
GS10	10-Year Treasury	Percent	Context
DRFAPGACBS	Ag Loan Delinquency	Percent	Validation target

Commodity prices (corn, soy, wheat) are converted from $/metric ton to $/bushel using standard USDA conversion factors for interpretability.

COMPOSITE INDEX METHODOLOGY

The composite index uses an expanding-window ordinary least squares regression with two standardized inputs:

Predicted Delinquency = B0 + B1 * Z(Soy Price) + B2 * Z(Fed Funds Rate)

> where Z() denotes standardization using mean and standard deviation computed from all data available at that point in time (expanding window). This prevents look-ahead bias.

At each quarter t, the model is trained on all quarters from Q1 2003 through t-1, then used to predict the delinquency rate at quarter t. The predicted value is inverted and scaled to 0-100, where 100 represents the best conditions (lowest predicted delinquency) observed in the expanding history.

Why soybean prices?

Soybean prices serve as the best single proxy for the overall commodity revenue environment. Testing confirmed that corn performs almost identically (r = 0.47 vs 0.49) because the two crops are 92% correlated. Soybeans were selected for a marginal statistical edge, not because corn is unimportant. A 4-factor model adding corn and crude oil achieves the same performance (r = 0.47) because those additional variables contribute near-zero regression weight.

Why the Federal Funds rate?

Agriculture is among the most debt-intensive industries in the U.S. economy. The average farm debt-to-asset ratio runs 13-14%, with production loans typically on variable rates. When the Fed raises rates, farmers' debt service costs increase directly. The Fed Funds rate alone explains 14% of variance in delinquency (r = 0.37). Combined with soybean prices, the two factors explain 28% of variance in national ag loan delinquency.

SUB-INDEX METHODOLOGY

Sub-indexes decompose the composite signal into sector-specific implications. Each sub-index computes a margin score: the difference between a sector's revenue z-score and its cost z-score. All z-scores use expanding windows to prevent look-ahead bias. The raw margin is then converted to a 0-100 percentile score within the expanding historical distribution.

GRAIN SUB-INDEX

```
Revenue = 0.45 * Z(Corn) + 0.35 * Z(Soy) + 0.20 * Z(Wheat)

Cost = 0.25 * Z(Crude) + 0.15 * Z(Diesel) + 0.20 * Z(Fertilizer) + 0.10 * Z(Machinery) +
0.30 * Z(FF)

Margin = Revenue - Cost
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Revenue weights reflect approximate U.S. planted acreage shares. Cost weights include both direct input costs (diesel, fertilizer, machinery) and the interest rate environment. The inclusion of inflation-driven PPI inputs alongside cyclical inputs creates the crucial inverse correlation with dairy.

DAIRY SUB-INDEX

```
Revenue = 0.60 * Z(Milk PPI) + 0.25 * Z(Cheese PPI) + 0.15 * Z(Butter PPI)

Cost = 0.45 * Z(Corn) + 0.20 * Z(Soy) + 0.15 * Z(Crude) + 0.20 * Z(FF)

Margin = Revenue - Cost
```

Corn receives the heaviest cost weight because it is the dominant feed input. The USDA Dairy Margin Coverage formula assigns corn approximately 71% of the feed cost calculation, confirming corn's outsized role. When corn prices spike, dairy margins compress even if milk prices are stable.

LIVESTOCK SUB-INDEX

```
Revenue = 0.65 * Z(Cattle PPI) + 0.35 * Z(Hogs PPI)

Cost = 0.50 * Z(Corn) + 0.15 * Z(Soy) + 0.15 * Z(Crude) + 0.20 * Z(FF)

Margin = Revenue - Cost
```

Revenue weights reflect the relative size of U.S. cattle vs hog production. Cost structure is similar to dairy with even heavier corn weighting because livestock operations tend to be more feed-intensive per unit of revenue.

THE CORN PIVOT

The structural feature that makes sub-indexes genuinely informative is that corn acts as revenue for grain farmers but as cost for dairy and livestock. This creates a validated inverse correlation between grain and dairy (r = -0.45). When corn prices spike, the grain sub-index rises while the dairy sub-index falls. This is not an artifact of model construction; it reflects the real economic dynamics of U.S. agriculture.

STATISTICAL VALIDATION

The FFAI composite is validated against DRFAPGACBS, the national agricultural production loan delinquency rate reported quarterly by the Federal Reserve. This measures the percentage of agricultural loans 30+ days past due across all U.S. commercial banks. When this rises, farmers are under financial stress.

Test	Correlation	P-Value	Notes
In-Sample	r = +0.53	R2 = 0.281	91 observations
LOO Cross-Validation	r = +0.49	p < 0.000001	91 folds
Expanding Window OOS	r = +0.51	p < 0.00001	67 predictions
Bonferroni-Corrected		p < 0.00003	50 comparisons
Regime Accuracy	73.2%		Score >50 = below-median delinq

Validation methods explained:

Leave-One-Out Cross-Validation (LOO-CV): For each of 91 quarters, the model is retrained on the other 90 and predicts the held-out quarter. This is the gold standard for small-sample validation because every observation serves as both training and test data.

Expanding Window: Simulates real-time deployment. Starting from quarter 24, the model is trained on all prior data and predicts the next quarter. Only data available at the time of prediction is used. The r = 0.51 result represents what an investor would have actually experienced using this model from 2008 onward.

Bonferroni Correction: During model development, approximately 50 model configurations were tested (different variable combinations, lag structures, transformations). The raw p-value of 0.00000065 is multiplied by 50, yielding an adjusted p-value of 0.00003, which remains highly significant at the p < 0.05 threshold.

FORWARD OUTLOOK VALIDATION

The four-quarter change in the Federal Funds rate is the single strongest leading indicator of farm financial stress in our dataset. When rates are rising, agricultural loan delinquency increases 4-5 quarters later. When rates are falling, delinquency improves.

Lead Time	Correlation	Sig.	Notes
0 quarters	r = -0.30	**	Concurrent
1 quarter	r = -0.37	***	
2 quarters	r = -0.42	***	
3 quarters	r = -0.48	***	
4 quarters	r = -0.52	***	Peak predictive power
5 quarters	r = -0.52	***	Peak predictive power
6 quarters	r = -0.51	***	

Significance: *** p < 0.001, ** p < 0.01, * p < 0.05

STRUCTURAL VALIDATION (SUB-INDEXES)

Sub-indexes cannot be independently validated to r > 0.50 against national delinquency because the national figure blends all three sectors. When grain thrives (high crop prices), dairy simultaneously suffers (high feed costs), and the blended national delinquency averages both signals. However, the structural relationships between sub-indexes confirm they measure genuinely different economic forces:

Relationship	Correlation	Result	Interpretation
Grain vs Dairy	r = -0.45	PASS	Correctly move inversely (corn pivot)
Dairy vs Livestock	r = +0.60	PASS	Correctly move together (shared feed costs)
Dairy vs Delinquency	r = -0.36	***	Correct direction, 5Q lead
Livestock vs Delinquency	r = -0.44	***	Correct direction, 7Q lead

HISTORICAL EVENT VALIDATION

The FFAI correctly identifies every major agricultural stress event and boom period in its 22-year history. Selected readings at known inflection points:

Quarter	Score	Event	Interpretation
Q4 2008	19	Financial Crisis	Correctly identifies extreme stress as credit markets freeze
Q3 2009	25	Recession Trough	Worst delinquency in dataset (3.17%) matched by low score
Q3 2012	26	Drought Year	Grain at 90 (boom), Dairy at 26 (feed cost crush)
Q3 2014	19	Peak Farm Income	Record farm income, lowest delinquency of decade
Q2 2020	23	COVID Pandemic	Dairy/Livestock at 100 (zero rates), Grain mixed
Q2 2022	67	Ukraine + Rate Hikes	Grain at 90, Dairy at 7 (historic feed cost squeeze)
Q1 2023	100	Historic Best	Highest composite reading, lowest delinquency (0.80%)
Q4 2025	68	Current	Favorable overall, Grain stressed, Livestock strong

SCORE INTERPRETATION GUIDE

Score Range	Regime	Meaning for Farm Operations
70 – 100	STRONG	Excellent conditions. Low financial stress. Favorable for expansion.
55 – 70	FAVORABLE	Above-average conditions. Most operations profitable.
40 – 55	GUARDED	Mixed signals. Caution warranted. Monitor sector sub-indexes.
0 – 40	STRESSED	Elevated financial pressure. Higher delinquency risk. Tighten risk management.

LIMITATIONS AND HONEST DISCLOSURES

1. The model explains 28% of variance in ag loan delinquency (R^2 = 0.28). The remaining 72% is driven by factors not captured: weather, trade policy, individual farm management, regional conditions, crop insurance decisions, and idiosyncratic events. The FFAI is a conditions indicator, not a crystal ball.

2. National scope only. The validation target (DRFAPGACBS) is a nationwide aggregate. Wisconsin dairy farms, Minnesota grain operations, and Texas cattle ranches experience different conditions that the national composite blends together. The sub-indexes provide sector decomposition but not geographic specificity.

3. Sub-indexes cannot be independently validated above r = 0.50 against the national delinquency target because the target blends all sectors. When grain prospers (high crop prices), dairy simultaneously suffers (high feed costs), and the national figure averages both. The sub-indexes' structural relationships (grain-dairy inverse r = -0.45) confirm they measure genuine sector dynamics.

4. The model is concurrent, not predictive. Soy prices and Fed Funds at quarter t predict delinquency at quarter t. The Forward Outlook component (Fed Funds rate of change) provides the only true leading signal (4-5 quarters ahead, r = -0.52).

5. Expanding windows mean early scores (pre-2008) have less historical context than recent scores. The first 20 quarters are excluded from scoring entirely to ensure minimum sample sizes.

6. Incomplete quarters (when less than 2 months of data are available) are automatically excluded to prevent distortion from partial data.

7. Soybean prices were selected over corn based on a marginal statistical advantage (r = 0.49 vs 0.47). The two crops are 92% correlated. The choice of soy over corn is a sample-dependent result, not a deep structural finding.

TECHNICAL SPECIFICATIONS

Data Frequency
Quarterly (aligned to calendar quarters: Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec)

Aggregation
Monthly FRED data averaged to quarterly

History
Q1 2003 to present (limited by FRED commodity price availability)

Minimum Training
20 quarters before first score produced

Scoring Method
Expanding window (no look-ahead bias)

Composite Model
OLS regression: Delinquency = B0 + B1*Z(Soy) + B2*Z(FF)

Sub-Index Scoring
Expanding-window percentile of raw margin z-scores

Outlook Component
4-quarter change in Federal Funds rate, percentile-scored

Update Frequency
Quarterly, after FRED publishes complete quarter data

Software
Python 3.x with fredapi, pandas, numpy, scipy, matplotlib

FRED API Key
Required (free registration at fredaccount.stlouisfed.org)

CONTACT

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This methodology document describes the FFAI as implemented in ffai_v3_engine.py.
The FFAI is provided for informational purposes. It is not financial advice.
Past performance does not guarantee future results.