



Using Grain Yield Estimates to Predict Commodity Prices



Market Grain Better

Underwrite Smarter

Lend Confidently

Executive Summary

Gain a new perspective on the changing dynamics of North American crop yield, the performance of USDA estimates, and how users can better anticipate revisions from the USDA to improve their crop marketing strategies – and ultimately **increase profits for their business**.

We provide readers with an overview of the latest technology and methods available to better understand how much is going to come out of the ground each growing season.

Additionally, we explore how **users can utilize cmdty Yield Forecast Indexes to predict USDA revisions**, and position their books and clients to profit from better information.

We also provide detailed information on how the following user types can drive performance for their business: **Crop Marketers, Ag Lenders, and Crop Insurance Underwriters**.

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Crop Production, Yields, and Technology

Crop production is directly impacted by yields through the relationship to acreage. Intuitively, harvested acres multiplied by the bushel per acre crop yield will derive the production of that area. However, the degree to which these two variables - acreage and yield - have contributed to overall growth in crop production over time is varied.

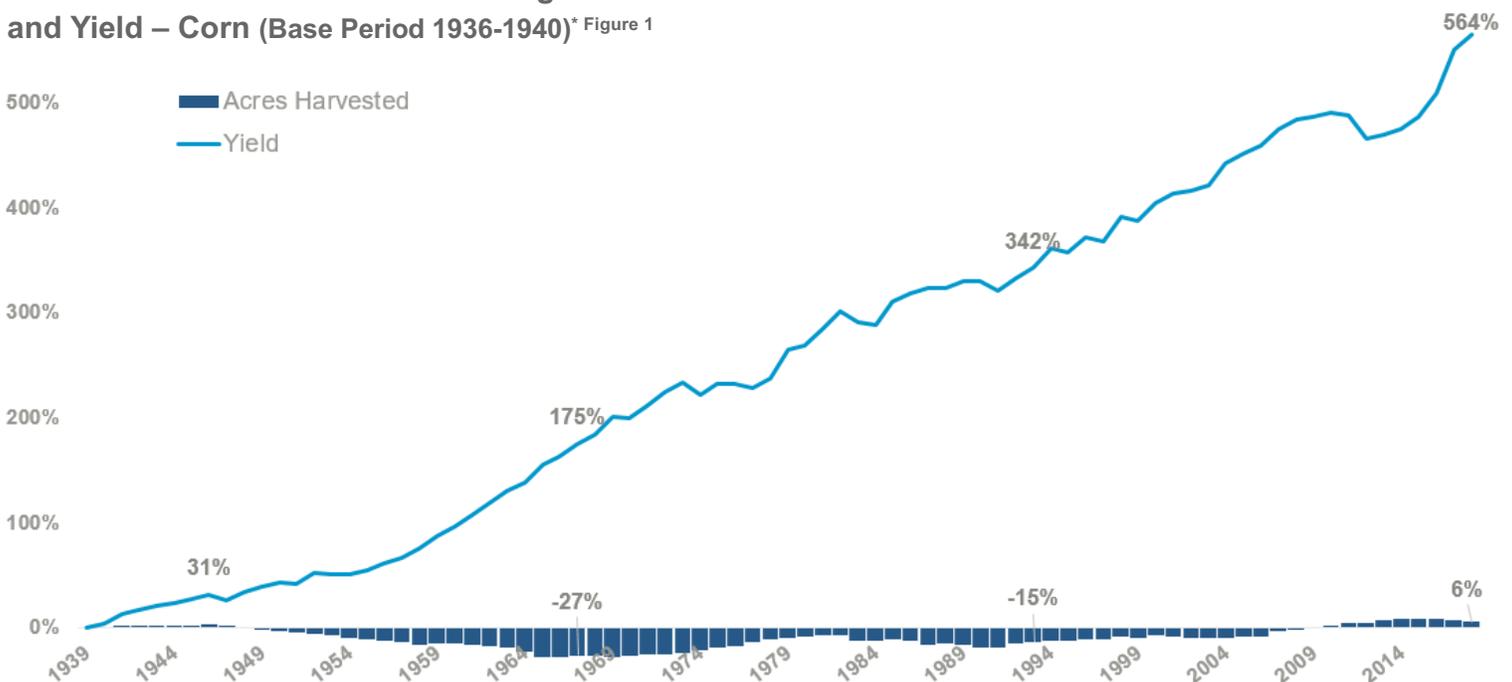
It's been nearly 60 years since Robert Finley, Professor of Agricultural Economics at the University of Missouri, remarked that, "even the most casual observer of agriculture has witnessed the increase in farm technology and efficiency over the past two decades."¹ Certainly, the growth seen in the period 1940-1960 was dramatic (3.26% CAGR) and resulted in a doubling of yields over the period; that said, the trajectory of growth in yield throughout the United States has carried on largely unabated since then.*

United States Yield and Compound Annual Growth Rate by Period (1940-2019)* Figure 2

Period	Starting Yield	Ending Yield	CAGR
1940-1960	27.1	51.4	3.26%
1960-1980	51.4	96.1	3.18%
1980-2000	96.1	131.8	1.59%
2000-2019	131.8	172.9	1.44%

Holding weather conditions and government programs as external factors that don't exert long-term influence on yield, then the growth we've seen over the past 80 years can be squarely attributed to advancement in the technology suite that is available to the grain community. This expanded definition of "technology" encompasses a wide variety of factors and may differ from how it is defined in non-agricultural circles.

Cumulative Growth of U.S. 5Y Average Acres Harvested and Yield – Corn (Base Period 1936-1940)* Figure 1



* Sources: cmdty, USDA. Yearly base and CAGR values represent rolling five-year average of U.S. production and yield figures

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For our purposes, we define technology in grain production as consisting of the following inputs – all of which have a direct impact to yield figures.

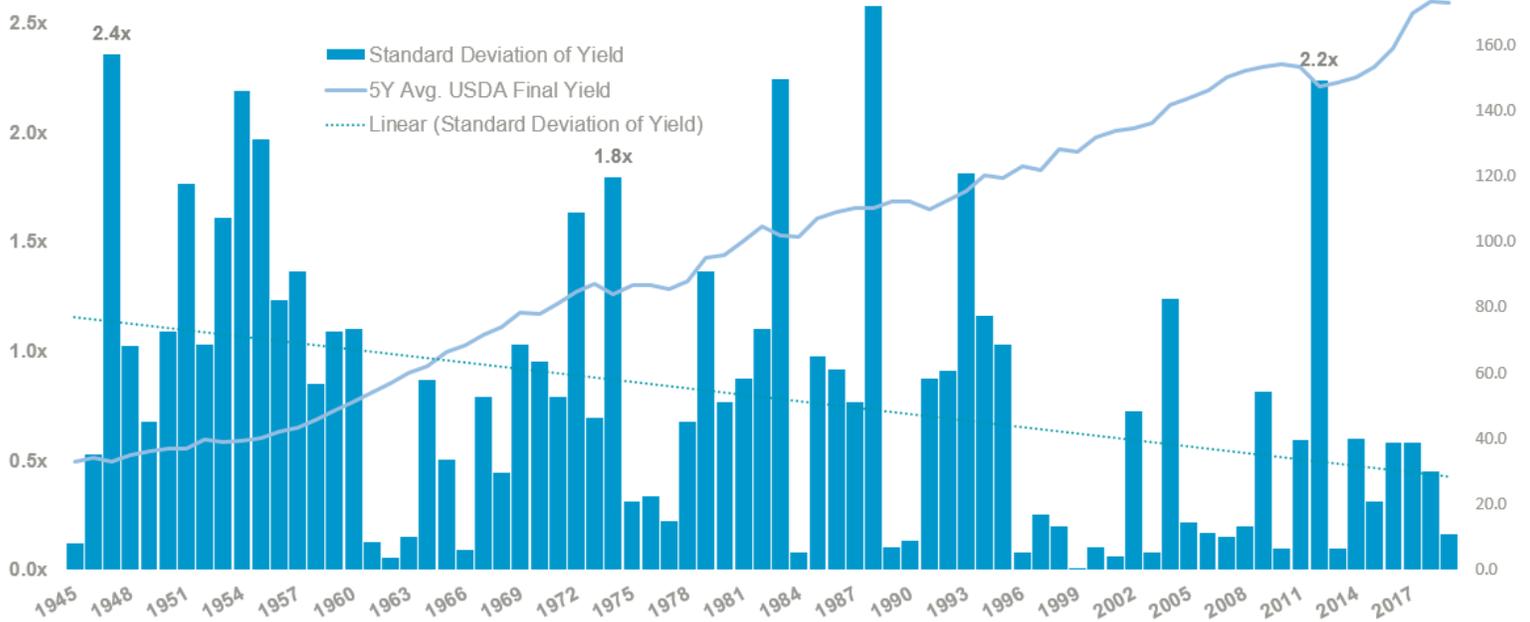
- Agronomy – The application of science to improve long-term crop production outcomes. As the data and tools available to agronomists has improved, so have the results.
- Machinery – Better machinery results in less waste and more efficient harvesting / processing of field crops.
- Genetics – Introduction of genomics into seed production has increased resiliency of harvests in developed economies.
- Field Applications – Advancements in crop protection and fertilization have reduced variability in yield.
- Data & Software – More data and better software has led to simplified decision frameworks and optimized farm operations

Each of these factors are interrelated with each other and have amplified the impact of any given factor on its own – a true positive feedback loop that has benefited the producer with continually higher yields. With acreage relatively fixed, this has resulted in greater sensitivity of grain markets to variability in yield figures.

Luckily, the upward trend in absolute yield has been accompanied by a reduction in variance for yield figures at the national level. In Figure 3 below, we see a clear trend towards reduced volatility in the percentage difference for expected yield for a given year,* and the actual yield that is reported through the USDA’s final US Crop Production Report.

To summarize, technology has served to improve yields with reduced variability – albeit with increased leverage to absolute yield values – at the national level.

Annual Standard Deviation of U.S. Corn Yield vs. Trend (1945-2019)* Figure 3



* Sources: cmdty, USDA. Linear yield trend model generated for period 1945 to 2019. Annual values represent absolute excess percentage returns expressed in the number of standard deviations from trend.

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How Yield Data Impacts Ag Markets

This gearing of production results in having an outsized weight towards yield figures – and it is intuitive that establishing estimates for yield has taken on increased importance over the same period. This is indeed true, and new information regarding yield expectations is incorporated by market participants almost instantaneously.

Currently, new information on yield expectations is primarily distributed to the market in two forms: the World Agricultural Supply Demand Estimates (“WASDE”) report which covers preseason estimates based on a linear trend model maintained by the USDA, and the USDA’s Agricultural Yield survey, which is a part of the monthly Crop Production Report. This report is released from August through November.

Information from both reports is voraciously consumed by the market and each release has historically generated outsized volume of trading relative to non-report days. As reported by the Wall Street Journal, Scott Irwin, a professor at the University of Illinois at Urbana-Champaign, has “estimated that volumes in corn futures in the minute after a report are 79 times higher than in the same minute on days with no report.”⁵

Leveraging what we established earlier in Figure 3, where annual standard deviation of corn production vs. trend has decreased over time, it reasons that estimates provided by USDA reports would become more accurate over time. This is indeed what academia has demonstrated with Scott Irwin, Darrel Good, and Dwight Sanders noting in farmdoc daily that “There is compelling evidence that the accuracy of USDA corn yield forecasts has improved over time, particularly since 2011.”⁶

A Closer Look



US Crop Production Report

The USDA Crop Production report contains information on crop production data for the U.S., including acreage, area harvested, and yield².

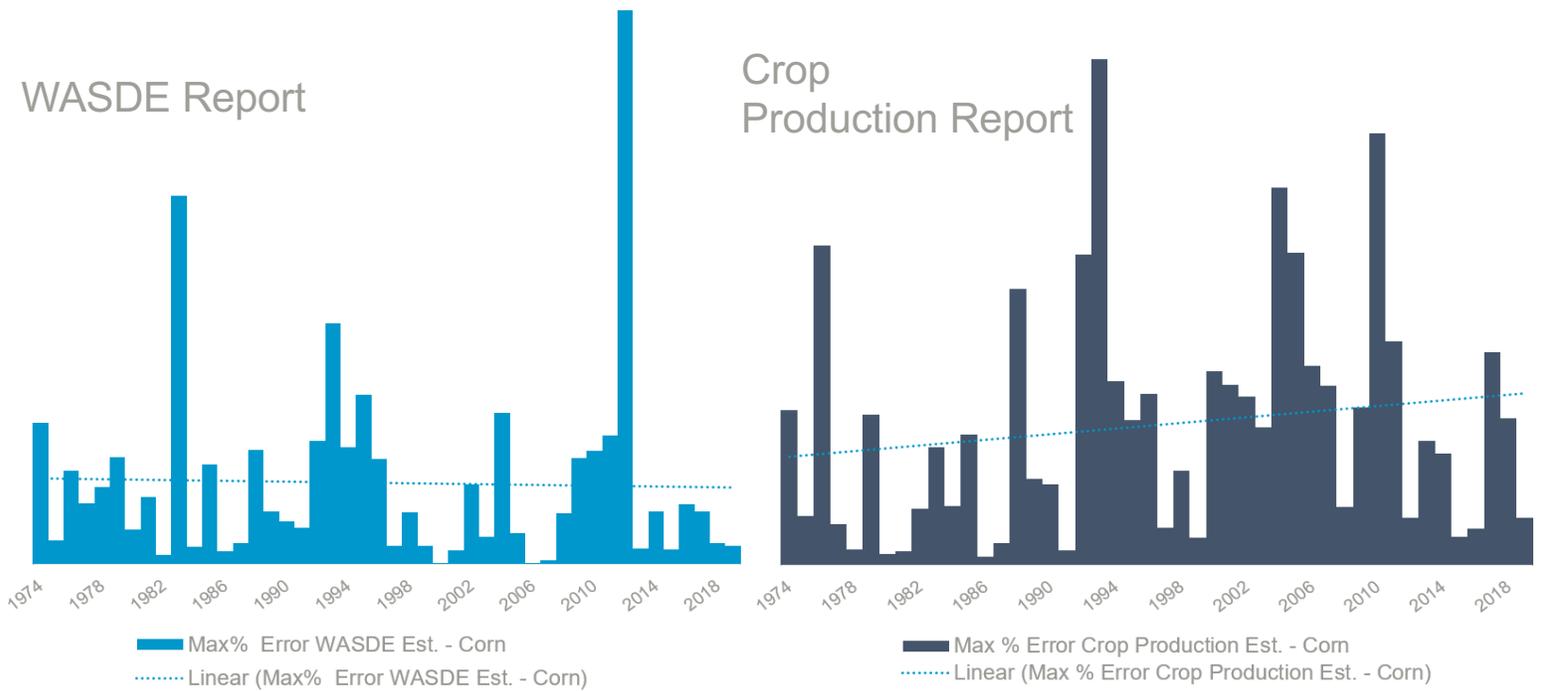
Reported monthly as part of the Crop Production Report, the Agricultural Yield Survey (“AYS”) provides farmer reported survey data of expected crop yields which are used to forecast and estimate crop production levels throughout the growing season. Additional data from a field measurement survey (“Objective Yield Survey”) is also incorporated. Information at the national and state level is provided for the contiguous 48 states³.

Historically, the monthly crop production report was subject to a “media lockup” that allowed for members of the media to have access to the report ahead the official release. In July 2018, the USDA announced the elimination of pre-release access by August 1st, 2018 and would be distributing the data exclusively through their website and other open data channels⁴.

These channels consist of updates to the USDA’s main page for the Crop Production Report, a series of “news reports” that are published to predetermined URLs, and distribution through the USDA’s open APIs. The transition to these services, and away from media lockups, resulted in diminished value of machine-readable distribution feeds that were previously being commercialized by certain members of the media cohort.

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Maximum Pct. Error by Year vs. Trend WASDE and Crop Production Reports (1974-2019) Figure 4



* Sources: cmdty, USDA. WASDE data represents the max percentage error from June and July releases vs. the final USDA yield figure. Crop Production data compares subsequent AYS results vs. final USDA yield figure. Area is U.S.

In Figure 4 we present data above that would seem to both align with and contradict the findings of Messrs. Irwin, Good, and Sanders. On the surface, it's clear that the linear trend for WASDE estimates is showing decreased errors over time, while the Crop Production numbers via the AYS farmer survey are increasing in variance. This however is not entirely accurate and is actually a bit misleading.

Intuitively it makes sense that WASDE is "improving" the initial estimates for yield – as we demonstrated in Figure 3 "Annual Standard Deviation of U.S. Corn Yield vs. Trend" the variance of final yield values vs. a linear trend model have been steadily decreasing over time. Since the estimates put forth in the June and July WASDE reports are derived from a linear trend model and don't incorporate farmer input, they should largely be following the trend established earlier.

Conversely, we see that the max error with estimates released through the Crop Production report have demonstrated a trend towards higher variance over time. While true, this observation is biased as sampling the max error percentage from the August, September, October, and November reports isn't necessarily the relevant statistic to measure "accuracy."

Average Absolute Percent Errors for USDA Corn Yield Forecasts (1990-2013)⁶ Figure 5

Years	Aug	Sep	Oct	Nov
1990-2013	4.19%	3.76%	2.01%	0.74%
1990-2001	5.07%	4.60%	2.71%	0.67%
2002-2013	3.32%	2.93%	1.24%	0.81%
t-statistic	-1.16	-1.49	-1.78	0.55
p-value	0.26	0.15	0.10	0.59

* Source: Irwin, S., D. Good and D. Sanders. "Are USDA Corn Yield Forecasts Getting Better or Worse over Time?." farmdoc daily (4):166, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, 2014-08-29

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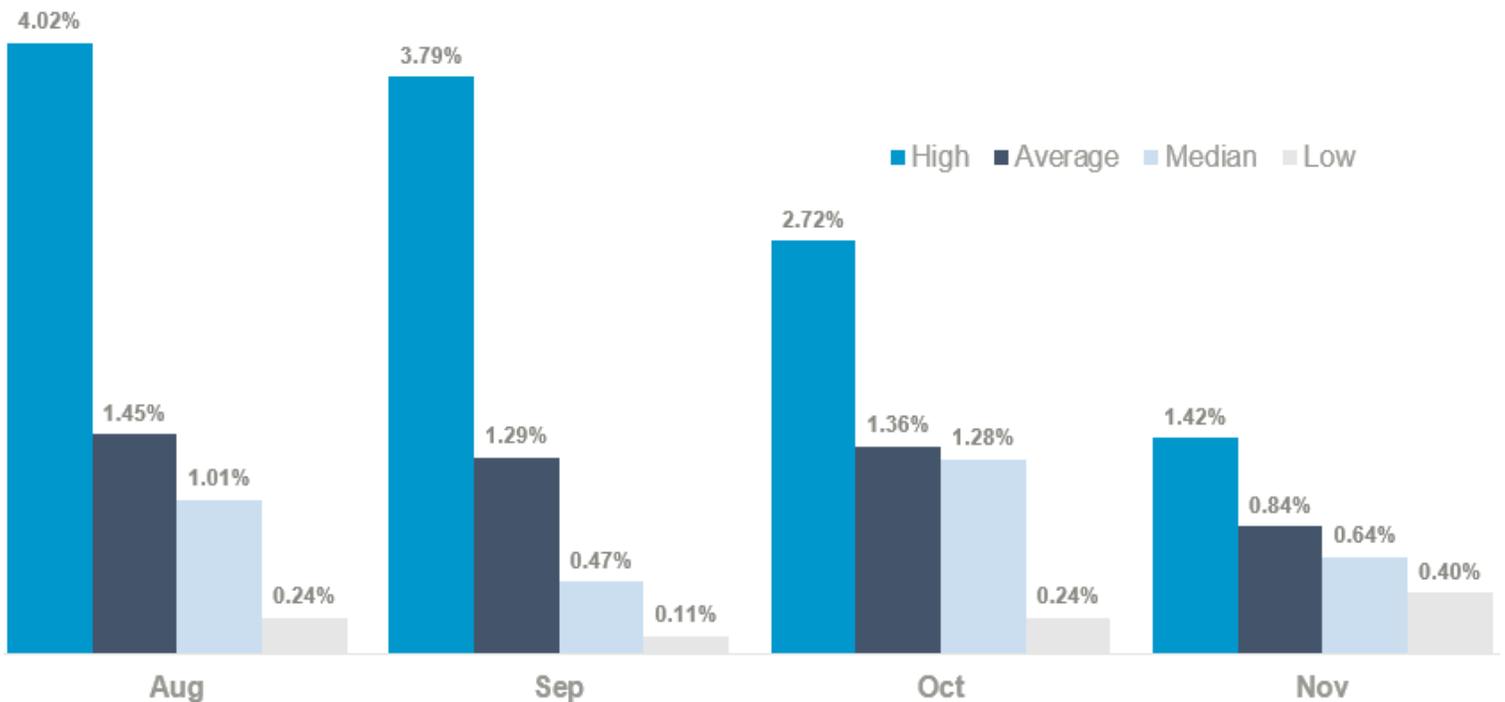
As demonstrated in Figure 5, the actual percent errors for yield estimates published in the Crop Production report clearly trend down from months August to November. So indeed the USDA is getting better at providing the market with accurate figures; however, there is still substantial variance in the estimated results that rely solely on survey data, with this variance being particularly acute in earlier reporting periods.

Expanding on the work of Irwin, Good, and Sanders, we present a similar story for the years that follow their initial findings. Figure 6 below shows the high, low, average, and median statistics for each monthly grouping of Crop Production reports during the years 2014-2019. As expected, the magnitude of errors

continue to decrease in later reporting periods by any relevant measure.

Interestingly though, despite a decrease in overall yield variance,^{Figure 3} and an improvement in the USDA's estimates vs. historical survey results⁶, there has not been a corresponding decrease in the volatility of price around the release of new yield data from the USDA.^{Figure 7} Not only is this surprising since actual yields are more predictable, and USDA estimates are less variable, but there are also tools available now – such as our cmdty Yield Forecast Indexes – that allow users to get ahead of the USDA's figures. **This suggests that despite reduced volatility in yield, there is still opportunity for crop marketers and ag underwriters to make better decisions around USDA estimate releases.**

Average Absolute Percent Errors for USDA Corn Yield Forecasts – Grouped by Report Month (2014-2019)^{Figure 6}



* Sources: cmdty, USDA. High, Average, Median, and Low values represent the relevant statistic for the report month groupings across 2014-2019. Median is the average of middle two values within each grouping

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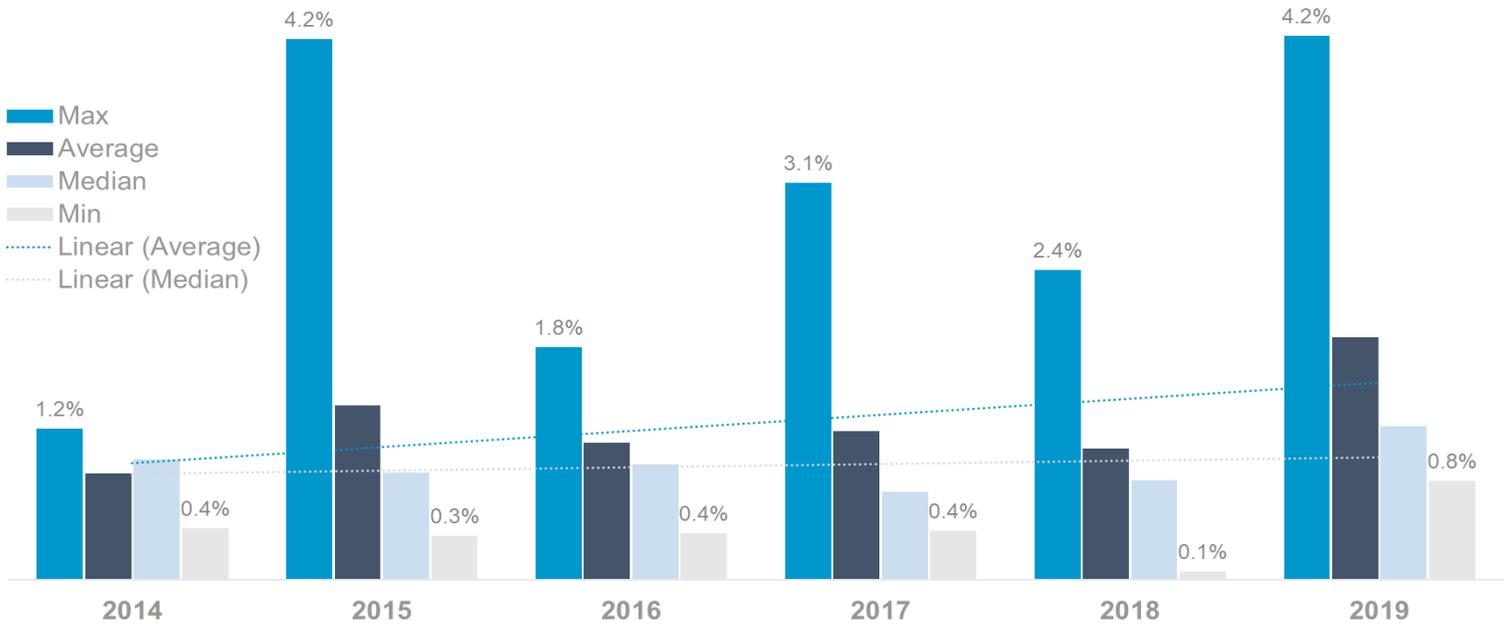
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Absolute Percent Price Change by Crop Year (Jun-Nov) in Minute After USDA Yield Estimate Release (2014-2019) Figure 7



* Source: cmdty. Average price change of most active futures contract on each report day. Change represents difference in closing price from close of 10:59 CST one-minute bar vs. closing price of 11:00 CST one-minute bar.

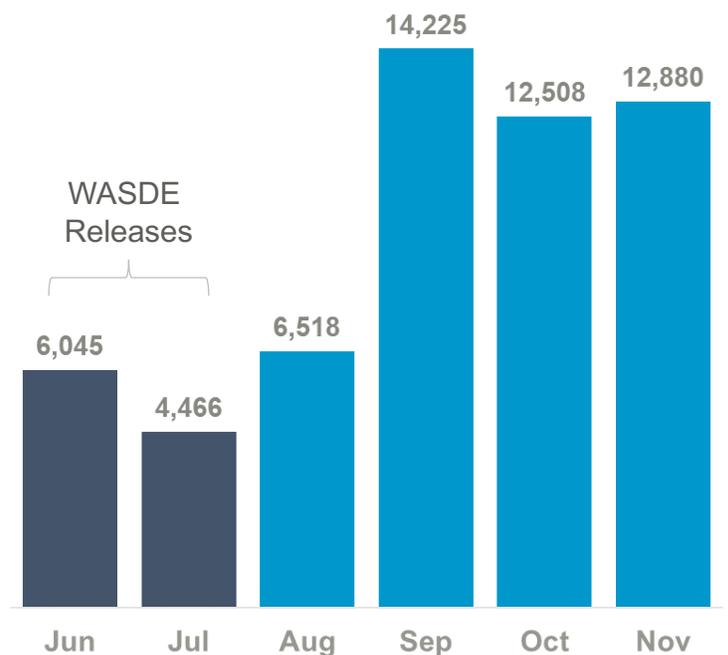
Price Activity from USDA Reports

In Figure 7 we measure the Max, Min, Average, and Median price movement* in the minute directly following the release of USDA yield estimates either through WASDE reports in June and July or the Crop Production Report thereafter. Somewhat surprisingly volatility for both the average and median values have trended higher over this period of time.

This observation has been corroborated by Karali, B., Isengildina-Massa, O., Irwin, S. H., Adjemian, M. K., & Johansson, R, who noted that, “The stable size of market surprises over time suggests that competition from alternative data sources has not reduced the news component of USDA crop reports.”⁷

While their studies focus on the impact of alternative data sources, and not on the trend towards reduced variance in field crop yields over time, it confirms our analysis that **price reactions to USDA reports have not decreased; and may actually be increasing.**

Average Volume in Minute After USDA Yield Estimate Release (2014-2019) Figure 8



* Source: cmdty. Average volume of most active futures contract on each report day for the one-minute period starting 11:00 CST and ending immediately before 11:01 CST

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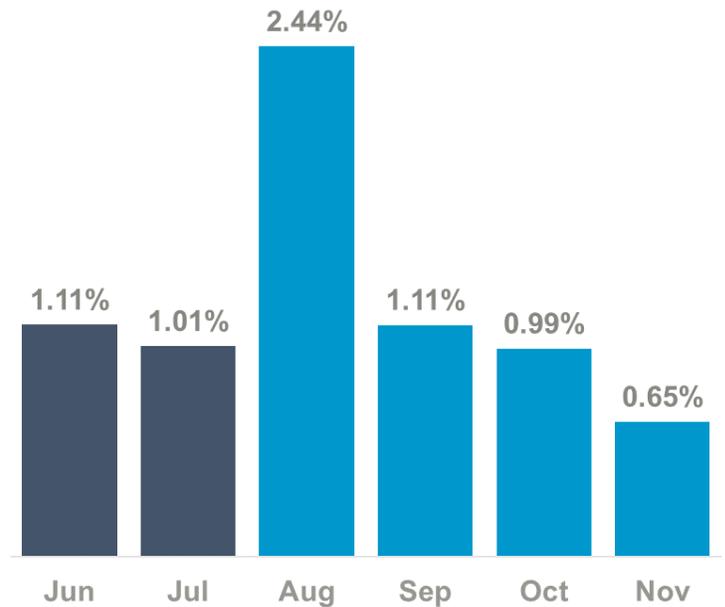
Figure 9 presents an even starker example of this pattern where we observe that specific reports have an outsized impact on price activity. For reports released exclusively via WASDE, and generated using only trend modeling, we observe that the absolute price movement within one minute of report release is meaningful at 1.11% and 1.01% for months June and July, respectively. However, this price movement is nearly 60% less than the average price movement generated by the release of the USDA's August report – which represents the first report using information from the Agricultural Yield Survey.

Not only is the price movement in the minute after a USDA yield and production estimate release elevated, but the volume (Figure 10) of contracts traded is elevated dramatically as well. This combination of price and volume activity represents new information being actively priced into the market in a short amount of time. As a result of this activity and information repricing, there is significant demand for estimates that may provide insights into the direction of USDA revisions.

Getting Ahead of the USDA

Collecting data and developing estimates for yield that can get ahead of USDA releases has historically been done through crop tours, or ground-based field reports, of major growing areas. However, such methods of data collection can be “costly, time consuming, and are prone to large errors due to incomplete ground observations.”⁸ For example, a popular crop tour that produces yield estimates relies on more than 100 “scouts” that drive across 20 different routes in the Midwest, and sample crops that are easily accessible by road every 15-20 miles.¹¹ This relative inefficiency has been a target of academics and commercial researchers going back to the eighties with early work

Average Percent Move in Minute After USDA Yield Estimate Release (2014-2019) Figure 9



* Source: cmdty. Average price change of most active futures contract on each report day. Change represents difference in closing price from close of 10:59 CST one-minute bar vs. closing price of 11:00 CST one-minute bar.

Average Volume by Minute for 15 Minute Period Surrounding USDA Yield Estimates (2014-2019) Figure 10

Period	Volume %	Cumulative Volume %
10:59	1.8%	1.8%
11:00	25.8%	27.6%
11:01	12.7%	40.3%
11:02	7.5%	47.8%
11:03	5.3%	53.1%
11:04	5.3%	58.3%
11:05	6.4%	64.7%
11:06	5.8%	70.5%
11:07	5.1%	75.6%
11:08	4.3%	79.9%
11:09	4.6%	84.5%
11:10	4.1%	88.6%
11:11	3.4%	92.0%
11:12	3.1%	95.1%
11:13	2.2%	97.3%
11:14	2.7%	100.0%

* Source: cmdty. Volume is relative to the 15 minute observation window as measured June-November for 2014-2019.

identifying remote sensing / satellites as potential sources for new information that could provide more accurate, resilient, and scalable sources for estimating yield and crop production. Specifically, the creation of and "extensive" use of the Normalized Difference Vegetation Index ("NDVI") "in vegetation monitoring, crop yield assessment, and forecasting" in the early eighties by researchers – see "A Numerical Crop Yield Model of Irrigated and Rainfed Agriculture" – marked a turning point in the adoption of remote sensing.¹⁰

While the idea of building yield models from known and hypothesized production variables, as opposed to simply surveying production, had been around for more than a few years in published works, the availability of remote sensing inputs that could reliably outperform mid-season survey-based estimates had not reached a point of maturity.¹² These earlier works from the 1970's were reliant on satellite imagery with low spatial resolution, and were relatively cost prohibitive. It was not until around 1990 that higher resolution remote images became available, and the costs to acquire and process them became more realistic for utilization in academic and commercial yield models.⁸

Over the next decade many academics began to investigate what variables other than NDVI could have a meaningful impact on the accuracy of non-survey based yield estimates. Most arrived on the same conclusions and consensus began to form around the variables which exhibited the greatest impact to realized yields. This academic coalescence is documented extensively by Prasad, Chai, Singh, and Kafatos in their "Crop yield estimation model for Iowa using remote sensing and surface parameters." We provide the reader with a summary of the most consistently cited variables used to build yield models.

A Closer Look



Key Variables Used in Yield Modeling

Normalized Difference Vegetation Index (NDVI) is a indicator that can be used to analyze remote sensing measurements, and assess whether the target being observed contains live green vegetation or not. Studies have shown that the NDVI is directly related to the photosynthetic capacity and energy absorption of plants.

Normalized Difference Water Index (NDWI) is strongly related to plant water content. It is therefore a proxy for plant water stress. Its usefulness for drought monitoring and early warning has been demonstrated in studies¹³

Land Surface Temperature - Land surface temperature is how hot the "surface" of the Earth would feel to the touch in a particular location.

Air Temperature – This is what you're familiar with day-to-day. The weather for better or worse.

Soil Moisture - Soil moisture is the water that is held in the spaces between soil particles. It's how wet the soil is.

Precipitation – Pretty simple, how much has it rained in the past day, week, month? You can't grow crops without water, but it's not the only factor.

Cropland Mask – A binary map separating annual cropland areas and other areas. These models are available from government bureaus and proprietary sources.

Using Grain Yield Estimates to Predict Commodity Prices

Building a Better Yield Estimate

With broader-based remote sensing information available now, and the technology to unlock its potential, what does this mean for those operating agribusinesses and providing services to these businesses through marketing advisory, lending, or insurance provision? Primarily, it suggests that solely relying on the USDA's estimates could mean that your firm is not providing clients with competitive marketing advice, or making lending and underwriting decisions on out-of-date or incomplete data.

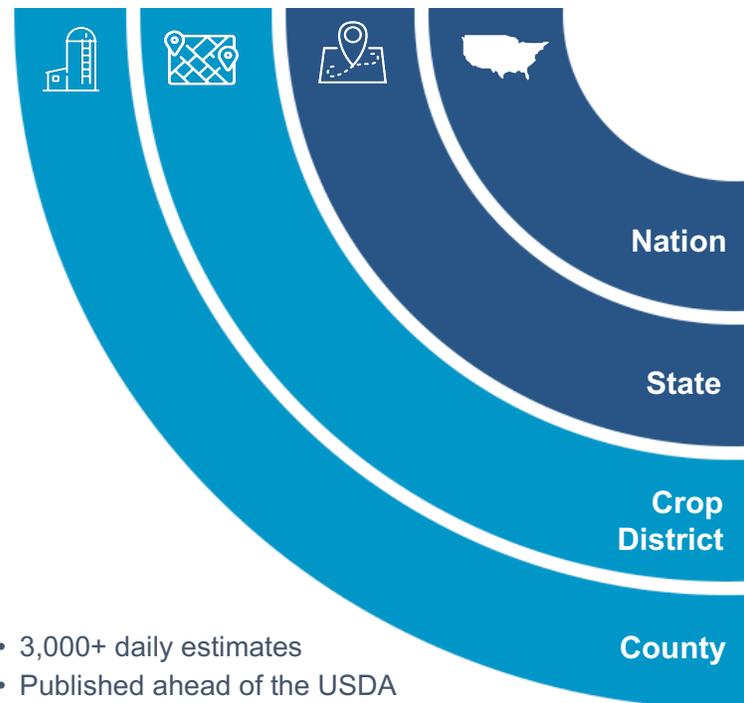
Producers rely on the latest in agronomy science, connected devices, and genomics to ensure they are getting the most out of the ground as possible; grain buyers, marketers, and underwriters should consider whether they are investing in their businesses the same way. While the fuel for a producer's business goes into the ground (seed, fertilizer) or operates upon it (machinery), what's becoming increasingly clear is that information is the fuel that grain marketers, ag underwriters, and firms serving agribusinesses run on.

“Information is the fuel that grain marketers, ag underwriters, and firms serving agribusinesses run on”

To serve these cohorts, we developed the cmdty Yield Forecast Indexes, which are a series of crop yield forecasts generated by our proprietary machine learning models. Similar to the USDA's yield forecasts, the cmdty Yield Forecast Indexes cover multiple geographical levels, from the county all the way up to a national level forecast, that provide users with broad-based coverage of yield expectations for Corn and Soybeans – with Wheat forecasts currently in development.

Higher frequency than USDA yield estimates, the cmdty Yield Forecast Indexes are recalculated every day from June to the end of harvest based on new information from remote sensing devices and observations from recent weather conditions for each growing area. In total over 3,000 individual estimates are updated each day.

Coverage for cmdty Yield Forecast Indexes for Corn and Soybeans Figure 11



- 3,000+ daily estimates
- Published ahead of the USDA
- Used for better grain marketing, ag lending, and crop insurance decisions

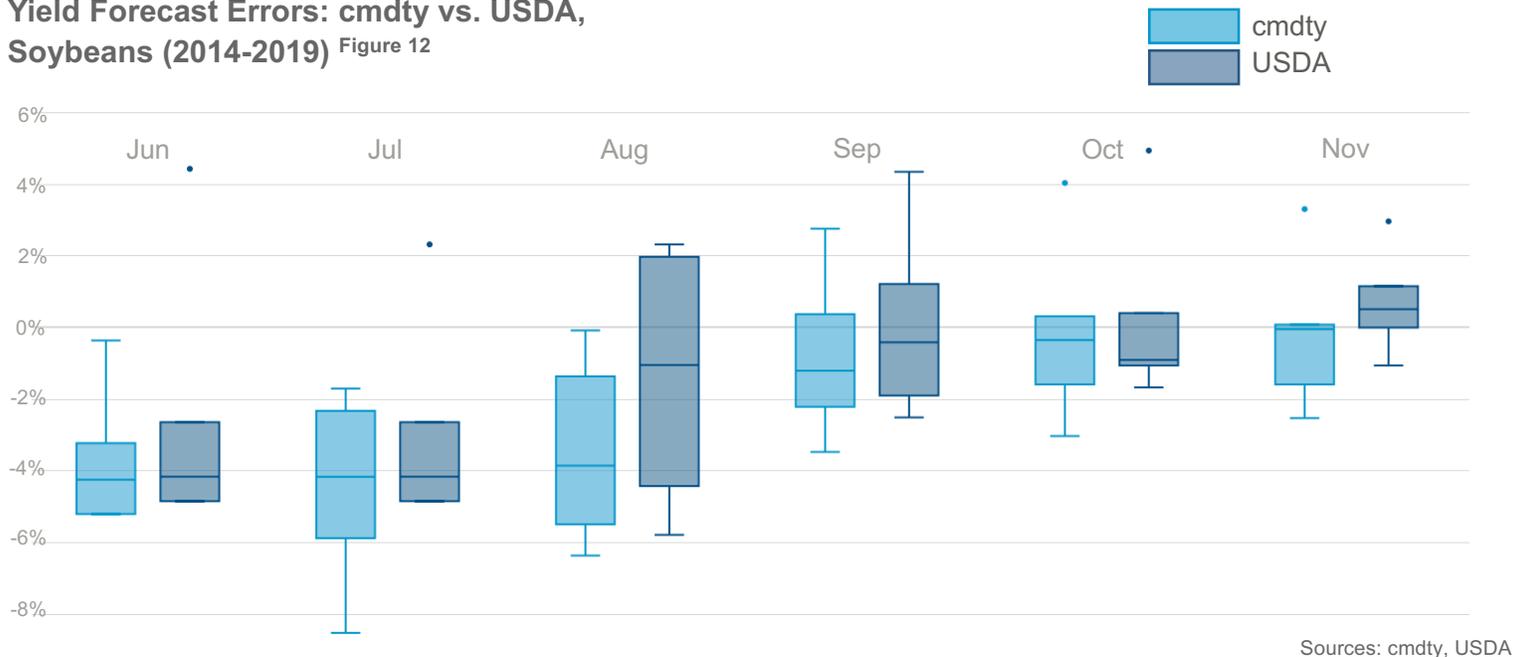
Source: cmdty

Benchmarking Performance to the USDA

To evaluate the accuracy of the cmdty Yield Forecast Indexes for Corn and Soybeans, the June, July, August, September, October, and November forecast errors are compared to USDA yield forecast errors. These error terms represent the difference between forecast and final values in percentage – where a positive error represents over-estimate, and negative error represents under-estimate.

Using Grain Yield Estimates to Predict Commodity Prices

Yield Forecast Errors: cmdty vs. USDA, Soybeans (2014-2019) Figure 12



Sources: cmdty, USDA

Figure 12 represents this comparison on error terms between the USDA estimates and cmdty Yield Forecast Indexes. These results are a point-in-time “apples to apples” comparison between the yield estimates available on the day of the relevant USDA release. There are a number of key observations which we discuss:

1. We can see accuracy increase along with the growing season for both USDA and cmdty estimates. Mean error gradually converges towards 0 representing diminished bias, and the standard deviation of each reporting period decreases resulting in subsequently smaller error ranges. These observations are intuitive as more information becomes available throughout the growing season whether that’s observed through survey data and crop tours or remotely sensed biomass and green vegetation levels.
2. Within the August reporting period, which is the first USDA report to incorporate survey results, the variance of USDA estimates, relative to final USDA

yield figures, is meaningfully higher than the variance of estimates delivered by cmdty. This is important as the August report (as shown in Figure 9) generates the largest amount of volatility in futures markets, relative to other report months, suggesting that access to the additional information provided through alternative estimates like those provided by cmdty may allow market participants to make better decisions ahead of this notoriously volatile report.

3. Estimates from September to November are mostly within a 2% error range and don’t meaningfully differ from each other. Both estimates perform at a similar high-accuracy level, but cmdty Yield Forecast Indexes are provided continuously throughout the growing season – instead of once per month. This allows users to always have up-to-date estimates and be less reactive to the USDA’s periodic reports.

For example, on Sep 9th, a user can access cmdty’s yield estimate with accuracy (mean -0.82% ,std 2.25%) – that compares to the USDA’s Aug Estimate (mean -1.33%, std: 3.37%). It’s no comparison.

Get better information faster than through traditional USDA Reports

Yield Forecast Indexes from cmdty allow you to stay ahead of the curve to confidently make better lending, pricing, and hedging decisions

WHAT YOU GET:



3,000+ Daily Updates

Get daily updated yield forecasts for your county, all the way up to the national level



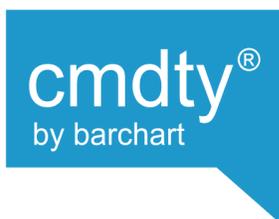
Historical Data

Our Historical forecasts are available all the way back to 2014 for Corn and Soybeans



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Predicting USDA Estimate Revisions

Understanding both the USDA and our yield indexes are predicting same thing from different models – one using a survey and the other a remote-sensing data driven machine learning model – and understanding that both predictions become less biased throughout the growing season, a natural question comes to mind: can we use cmdty Yield Forecast Indexes to estimate future revisions of USDA forecast?

$$Y_{USDA}^{Final} = Y_{cmdty}^t + \epsilon_{cmdty}^t$$

$$Y_{USDA}^{Final} = Y_{USDA}^t + \epsilon_{USDA}^t$$

$$Spread^t = Y_{cmdty}^t - Y_{USDA}^t$$

$$Spread^t = \epsilon_{cmdty}^t - \epsilon_{USDA}^t$$

There is potential information asymmetry between those market participants that aren't updating their yield forecasts between USDA reports and those that are. Based on the patterns presented in Figures 7 & 9, where volatility around the USDA's release is actually increasing, it reasons that there is still a large cohort of users that still rely entirely on the USDA's monthly estimates for their own yield models.

Of specific interest is the potential to use the daily updates provided by cmdty to gain insights into the direction of the upcoming USDA revision; providing users with insight into the national crop production landscape that wasn't previously available.

From historical data, we can tell USDA forecast error, ϵ_{USDA}^t , and cmdty's, ϵ_{cmdty}^t , both converge to 0, and have less variance along growing season passes. If history results remain, we can expect there is a

threshold, T , for any t within growing season, $Spread^t$ is most likely fall in the range $[-T, T]$. This threshold monotonically decreases as the growing season progresses. Without losing generality, we can consider threshold as a constant range that is expected to contain spread at all times.

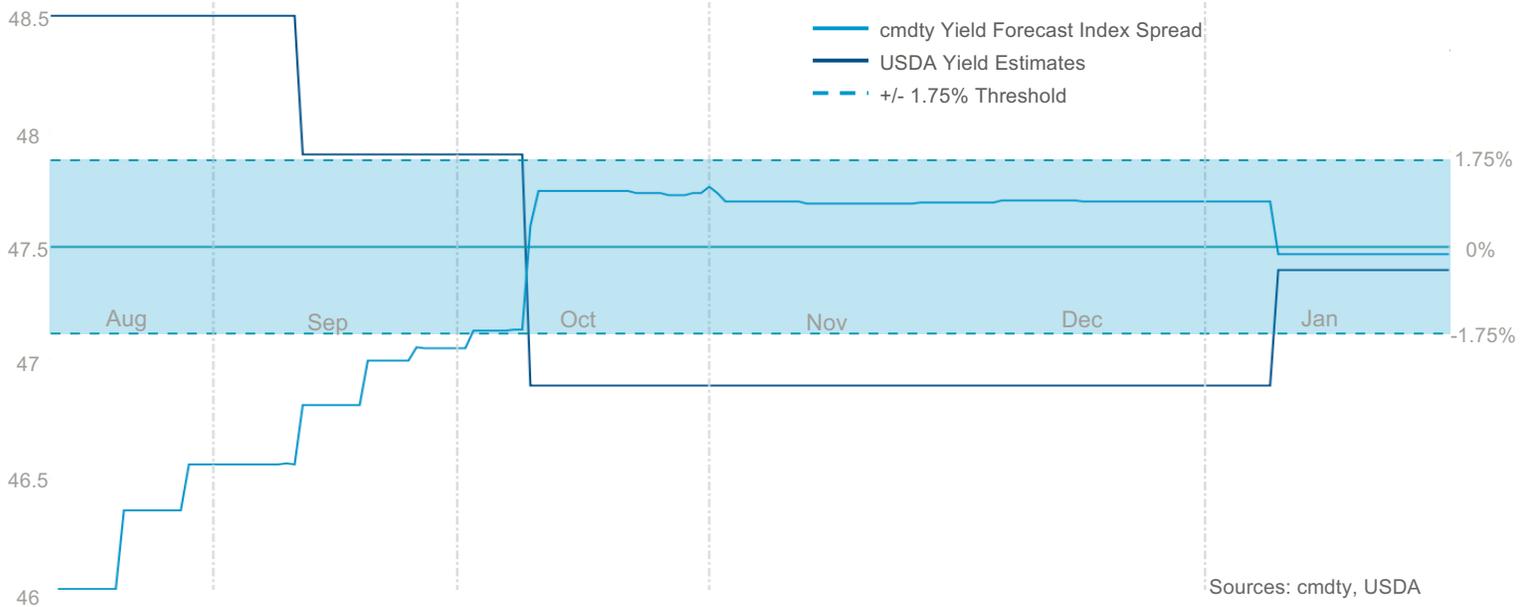
In reality, USDA forecast is released at mid-month, but refers to the beginning of the month. Therefore, at the beginning of the month, observers of yield estimates have access to a current month cmdty forecast, Y_{cmdty}^t , but only a preceding month USDA forecast, Y_{USDA}^{t-1} . Sometimes, the cross month spread falls out the constant range, $|Y_{cmdty}^t - Y_{USDA}^{t-1}| > T$, but we expect the same month spread falls inside the constant range, $|Y_{cmdty}^t - Y_{USDA}^t| < T$, so we expect the USDA to revise their estimates toward the direction that reduces the spread term within the threshold bound.

For example, on September 1st, users will have access to cmdty Yield Forecast Indexes through to that date, but only access to the August USDA yield estimate. Assuming that the forecast provided by cmdty is meaningfully higher than the USDA's (which it was in 2019), and this spread is higher than a reasonable range based on historical data, it is intuitive to expect the USDA unreleased September USDA yield estimate will be higher than August USDA yield estimate. Depending on the spread, and it's relationship with the threshold, a user may be incented to proactively position their portfolio ahead of the USDA's September report.

To validate this hypothesis, we compared the forecast spread to the USDA's historical forecast revisions. A range of 1.75%, between current cmdty forecasts and the most recent USDA estimate empirically delivered the highest potential profit based on the number of opportunities available and the profit per opportunity.

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cmdty Forecast Spread vs. USDA Estimate
Revision – Soybean 2019 Figure 13



The results from a historical analysis well supported our hypothesis. For example, we see in Figure 13 that the pattern of convergence between cmdty Yield Forecast Indexes and the USDA national yield estimates for soybeans in 2019 was well intact. Additionally, the magnitude of the USDA’s correction tended to be more pronounced in periods where the spread between the two estimates diverged more significantly. Based on our analysis, we can predict with strong accuracy whether the USDA is highly likely to increase or decrease its forecast at the next scheduled report.

“we can predict with strong accuracy whether the USDA is highly likely to increase or decrease its forecast at the next scheduled report”

We will explore this at length in the subsequent section.

Practical Implications & Trading Model

According to USDA, the Harvest Acreage Forecast won’t change significantly since Aug Crop Production Release, thus any change of yield forecast will generally have a direct transmission into a change of official Production Estimates.¹⁴ Considering the impact of USDA production estimate on futures market, we came up with a basic trading strategy to validate the profitability of using cmdty Yield Forecast Indexes to inform positioning in futures markets.

The logic for our model is driven by the spread between cmdty Yield Index and USDA yield forecast. If this spread is +/- greater than our 1.75% threshold at the beginning of month, we speculate that:

- The USDA will revise their yield forecast towards the cmdty forecast WASDE report
- USDA will revise their production forecast in WASDE report
- CBOT corn and soybean futures will inversely follow the revision of the USDA’s estimate

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For this simulation model, we do not consider the spread from the linear model driven preseason forecast, because the accuracy is low and less meaningfully related to year end yield figures than the in-season survey based estimates provided in September through November.

Model Results - Corn

Assuming an investment of 10 futures contracts per “signal”, our modeled results for corn are presented in Figure 14 and below.

- Signals were generated on 14 report days from Sep 2014 to Jan 2020, with net profit \$19,375.
- On 12 of 14 report days, the USDA revised estimates towards our expectation resulting in a PnL of \$24,375 in total from these trading days.
- On 2 of 14 report days, the USDA did not revise their yield estimates as expected, which generated a loss of \$5,000 in total.

A Closer Look



A Methodology for Profiting From Variance in Yield Estimates

For months September, October, November, and January, if the spread between the cmdty Yield Forecast Index for the U.S. and the USDA yield forecast is higher than our threshold of 1.75% and “today” is a WASDE report day, then we

Buy most active futures contract at market open if
cmdty estimate > USDA estimate

Or

Sell most active futures contract at open if cmdty
estimate < USDA estimate

Then

Exit our position at the market close

Simulated Results From Trading on Variance in Yield Estimates – Corn (2014-2020) Figure 14

Symbol	Year	Report	Open	Close	USDA Revision	Forecast Spread	Revision Prediction	PnL
ZCZ14	2014	November	366.00	369.25	-0.46%	-2.54%	Correct	\$1,625
ZCH15	2015	January	399.00	402.00	-1.38%	-2.09%	Correct	\$1,500
ZCZ15	2015	September	374.00	387.00	-0.77%	-2.07%	Correct	\$6,500
ZCH16	2016	January	352.00	356.75	-0.53%	-1.93%	Correct	\$2,375
ZCZ16	2016	September	340.50	339.50	-0.40%	-2.29%	Correct	(\$500)
ZCZ17	2017	September	357.00	351.50	0.24%	2.72%	Correct	\$2,750
ZCZ17	2017	October	346.00	349.00	1.12%	4.28%	Correct	(\$1,500)
ZCZ17	2017	November	347.50	341.50	2.10%	3.09%	Correct	\$3,000
ZCZ18	2018	October	362.00	369.25	-0.33%	-2.01%	Correct	\$3,625
ZCZ18	2018	November	372.00	373.50	-1.00%	-1.85%	Correct	\$750
ZCZ19	2019	September	360.75	367.25	-0.77%	-6.23%	Correct	\$3,250
ZCZ19	2019	October	392.75	380.25	0.12%	-4.48%	Incorrect	(\$6250)
ZCZ19	2019	November	375.25	377.25	-0.83%	-3.93%	Correct	\$1,000
ZCH20	2020	January	383.25	385.75	0.60%	-3.10%	Incorrect	\$1,250

* Source: cmdty. Results simulated and based on going long or short 10 corn contracts ahead of USDA releases subject to spreads between USDA estimates and cmdty Yield Forecast Indexes. PnL figures are independent per “trade” and do not represent cumulative PnL figures.



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Using Grain Yield Estimates to Predict Commodity Prices

Simulated Results From Trading on Variance in Yield Estimates – Soybeans (2014-2020) Figure 15

Symbol	Year	Report	Open	Close	USDA Revision	Forecast Spread	Revision Prediction	PnL
ZSX14	2014	September	992.00	981.50	2.64%	3.88%	Correct	\$3,150
ZSX14	2014	October	939.50	922.5	1.07%	2.08%	Correct	\$5,100
ZSH16	2016	January	861.25	874.5	-0.62%	-2.17%	Correct	\$3,975
ZSX16	2016	September	978.00	964.25	3.48%	2.54%	Correct	\$4,125
ZSH17	2017	January	1009.75	1040.25	-1.14%	-3.50%	Correct	\$9,150
ZSX17	2017	September	960.75	950.50	1.01%	2.17%	Correct	\$3,075
ZSX17	2017	October	965.00	992.00	-0.80%	2.91%	Incorrect	(\$8,100)
ZSF18	2018	November	998.25	985.00	0.00%	3.39%	Incorrect	\$3,975
ZSH18	2018	January	948.25	960.50	-0.40%	2.83%	Incorrect	(\$3,675)
ZSX18	2018	October	852.00	858.25	0.57%	-3.81%	Incorrect	\$1,875
ZSF19	2019	November	879.25	879.00	-1.88%	-4.63%	Correct	(\$75)
ZSH19	2019	February	913.00	914.50	-2.88%	-2.86%	Correct	\$450
ZSX19	2019	September	871.00	895.50	-1.24%	-4.39%	Correct	\$7,350
ZSX19	2019	October	919.50	923.50	-2.09%	-2.05%	Correct	\$1,200

* Source: cmdty. Results simulated and based on going long or short 10 soybean contracts ahead of USDA releases subject to spreads between USDA estimates and cmdty Yield Forecast Indexes. PnL figures are independent per “trade” and do not represent cumulative PnL figures.

Model Results - Soybeans

Assuming an investment of 10 futures contracts per “signal”, our modeled results for soybeans are presented in Figure 15 and below.

- Signals were generated on 14 report days from Sep 2014 to Jan 2020, with net profit \$31,575.
- On 10 of 14 report days, the USDA revised estimates towards our expectation resulting in a PnL of \$37,500 in total from these trading days.
- On 4 of 14 report days, the USDA did not revise their yield estimates as expected, which generated a loss of \$5,925 in total.

Results Summary

Between the years 2014-2020 we are able to generate, what we classified as significant, signals 28 times in total between corn and soybeans. The results generated by these signals were impressive and in

total accurately predicted the direction of the USDA’s estimate revisions 22 out of 28 times over the observation period. We also generated positive PnL on 22 out of 28 trades that were simulated over this same period, resulting in a total PnL of \$50,950 on a trade size of 10 contracts per trading opportunity.

“we accurately predicted the direction of USDA estimate revisions, and generated positive PnL on over 75% of opportunities from 2014-2019”

The results of this model are interesting to speculators and hedgers, but these outcomes can be applied to much more than just building an outright trading strategy. Specifically, we explore the implications of this model to the following cohorts: Crop Marketers, Crop Insurance Underwriters, and Ag Lenders.

Using Grain Yield Estimates to Predict Commodity Prices

Outcomes and Use Cases

No one is debating that having better information around USDA yield and production forecast releases is important, but the big question is what to do with this sort of information. Here are some concrete examples of how clients can use cmdty Yield Forecasts Indexes to increase profits and make better decisions easier than they ever have before.

Crop Marketers

Crop marketers and Market Advisory Services ("MAS") firms need to have a clear view on price risks both to the upside and downside for futures and basis prices. With improved information these market participants are able to better employ marketing strategies that secure cash flow when beneficial, and reduce price risk by optimizing contract structures to future expectation.

For instance, a crop marketer with insight into the likely direction of the USDA's yield and production estimate revision, which may be possible by using

cmdty Yield Forecast Indexes as shown in Figures 14 and 15, would be able to structure their grain portfolio to benefit from either an expected increase or decrease in futures prices. If this marketer expected futures to increase at the next USDA report, and had the expectation that basis in their area was likely to weaken, they could enact any of the following strategies to generate the highest possible return from their managed crops:

- Enter into a basis contract
- Sell cash and buy futures
- Buy a call option
- Enter into a minimum price contract

Combined with cmdty Basis Forecast Indexes, a marketer or MAS provider could scalable develop highly targeted marketing strategies for hundreds of different production areas in one simple tool. Whether working for themselves or clients, an informed crop marketing strategist can generate real value with these products.

Impact of Pricing Expectations on Grain Marketing Strategies Figure 16



Sources: Adapted from "Developing Marketing Strategies and Keeping Records on Corn, Soybeans, and Wheat", NCR 215-4, December 1985

Using Grain Yield Estimates to Predict Commodity Prices

Crop Insurance

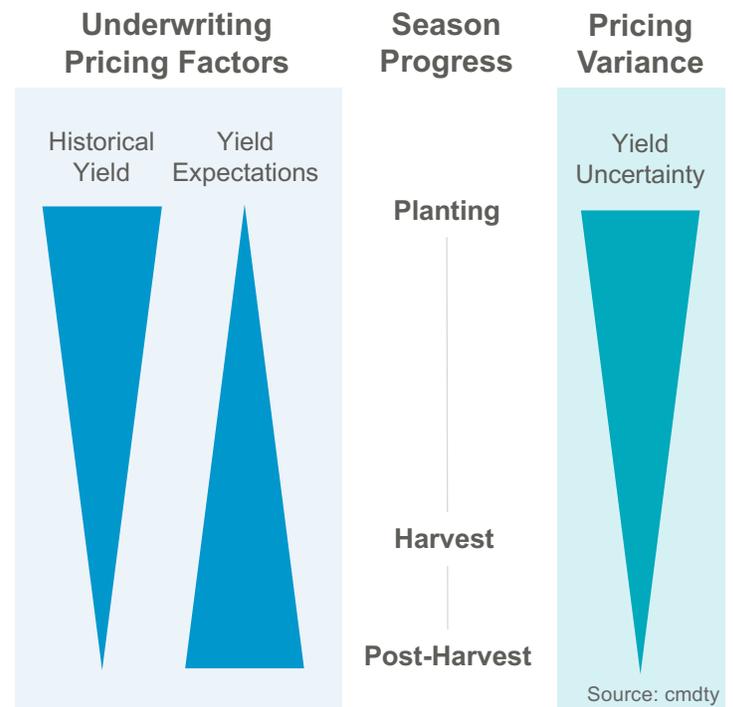
There are two general categories of crop insurance: Crop Yield Insurance, and Crop Revenue Insurance.¹⁵ While only one explicitly mentions “Yield” in the name both are inextricably linked to the amount of grain that comes out of the ground.

- Yield-based crop insurance policies pay farmers for a percentage of yield shortfalls relative to their average crop history or the average yields in their county. Farmers can select the percentage of yield differential they will receive. Unit prices are based on the pre-planting price per unit set in futures contracts¹⁵.
- Revenue-based crop insurance policies compensate farmers for shortfalls in crop revenues relative to their baseline averages and may also allow for increased payments if harvest prices exceed planting season prices¹⁵

Needless to say, getting a better view on yield is an important component to building strong underwriting models – which rely on not just realized historical yield, but also historical variance and potential variance in calculating insurance premiums. Additionally, depending on when the contract is written during the growing season, the contract will be priced more inline with historical yield or with yield expectations for the current season. ^{Figure 17}

With cmdty Yield Forecast Indexes, insurance underwriters can estimate production and variance more effectively with yield estimates available at the county level. With more risk insights available, it allows underwriters to price more aggressively and accurately than just relying on USDA published information. Additionally, with our demonstrated ability to inform the direction of USDA estimates, underwriters can opportunistically hedge their book to improve their loss ratio across their entire portfolio.

Yield Impact to Crop Insurance Underwriting by Growing Season Progression ^{Figure 17}



In addition to the Yield Forecast Indexes with County, CRD, State, and National benchmarks for Corn, Beans, and Wheat, you can more precisely structure your contracts to reflect where grain trades in each underwriting area. Stop paying out your contracts on general futures prices, and instead more accurately structure payments depending on local pricing information – matching how your Yield and Revenue calculations are structured.

“estimate production and variance more effectively with yield estimates available at the county level”

Our products power your underwriting models with better information so your business can make improved decisions. With advanced yield estimates, forward basis projections, and cash benchmarks, you can build a more effective insurance platform.

Using Grain Yield Estimates to Predict Commodity Prices

Ag Lenders

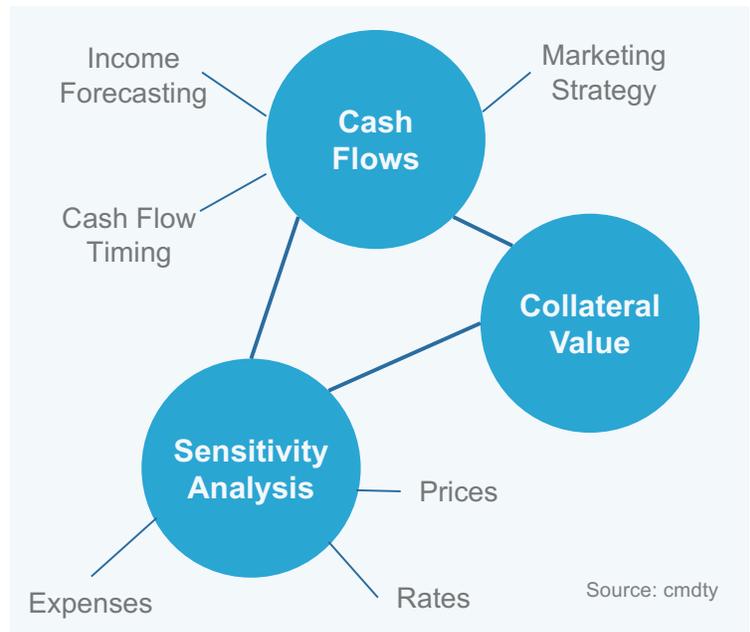
The role of the ag lender, and the composition of the firms in this space has evolved significantly over time and continues to evolve to this day. As technology has improved, and the ability to price and monitor a loan from anywhere in the country has emerged, more players are competing for ag lending business and more non-traditional lenders have entered the space.¹⁵

No longer is physical proximity and available balance sheet the only differentiator for ag lenders, but being able to serve as partners for their producers allows today's lenders to differentiate their services and provide better pricing – as more cash flow and expense management as a service become a part of the lending experience. In other words, while ag lending continues to be centered around understanding the expected cash flows of the business, successful lenders will add their expertise through scalable processes and data analysis capabilities that are difficult for each individual producer to manage on their own.

This is particularly true in the case of marketing grain, as not only is it one of the most important pieces of managing an operation, but it is a key driver of the cash flows that ensure repayment of committed capital. Ag lenders that are able to provide sound crop marketing advice, not only help their growers, but they help themselves with better loan performance. This all benefits producers, as lenders with better loan performance can be more aggressive on pricing, which intuitively means that more marketing strategies will originate from the lender as the market evolves.

With the cmdty Yield Forecast Indexes, and their ability to inform estimate revisions from the USDA we provide ag lenders a powerful tool that they can use

Key Lending Factors and Underlying Drivers for Ag Lending Figure 18



in building out competitive crop marketing plans for their producers. These yield estimates, when used alongside our forward prices for cash grain, allow lenders to better estimate production value and ultimately provide more competitive pricing, while reducing risk.

Additional value adds for ag lenders

- **Collateral Valuation** – Finally a simple way to value collateral both on a cash and forward basis. Use our objective pricing benchmarks to match anticipated cash flows
- **Basis Projections** – Use our basis projections in combination with yield estimates to build the most advanced crop marketing model in the industry
- **Sensitivity Analysis** - Use our historical production data, forward yield estimates, and benchmark pricing for basis and cash to help you run sensitivities on cash flow and repayment ability
- **Income Forecasting** – Easily understand what price a producer will get for their crop by using our tools

Using Grain Yield Estimates to Predict Commodity Prices

Conclusion

While the market has seen continued improvements in yields, with reduced variance at the national level, and the USDA has gotten better at providing estimates, there continues to be significant volatility around the release of USDA yield and production forecasts.

By using the cmdty Yield Forecast Indexes, we were able to predict the direction of USDA revisions with over 75% accuracy. Our simulated trading model also generated a positive PnL, with positive results that were over 75% accurate as well.

Users of these indexes can leverage this information to make better decisions for their business with improved marketing strategies, underwriting performance, and lending best practices. When used alongside cmdty's price benchmarks, basis forecasts, and commodity fundamentals data, our clients are able to create powerful models that can differentiate their business from others.

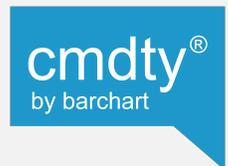
cmdty Yield Forecast Indexes

Get ahead of the curve with access to high-performing yield predictions - get better information faster than through traditional USDA reports.

With daily updated yield forecasts for your county, all the way up to the national level, and available historically back to 2014, our yield estimates provide users with a powerful tool that adds value to both individual uses and enterprises that need to scale.

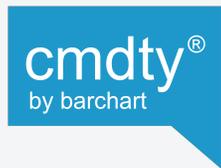
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